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**Oda et al.**

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(54) **SOLID-STATE IMAGE PICK-UP DEVICE  
AND DIGITAL STILL CAMERA**

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(73) Assignee: **FUJIFILM Corporation**, Tokyo (JP)

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 714 days.

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*Primary Examiner*—David Ometz

(22) Filed: **Apr. 8, 2003**

*Assistant Examiner*—Wanda M. Negron

(65) **Prior Publication Data**

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(57) **ABSTRACT**

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In a solid-state image pick-up device comprising photoelectric converting devices **3r**, **3g** and **3b** formed at a predetermined array interval in row and column directions on a semiconductor substrate, vertical transfer paths **4a**, **4b**, **4c**, . . . provided in the column direction of the photoelectric converting device and serving to read and transfer a signal charge obtained by the photoelectric converting device, and a shielding film for covering an upper part of the vertical transfer path, a pore **7** is provided in a place corresponding to an imaginary pixel point position in the shielding film. Consequently, an actual signal (an imaginary pixel point charge) corresponding to the amount of a received light on the imaginary pixel point through the pore **7** is stored in the vertical transfer path. Therefore, the imaginary pixel point charge is read from the solid-state image pick-up device before the signal charge is read from the photoelectric converting device, and image data based on the signal charge are corrected by the actual imaginary pixel point charge. Thus, it is possible to generate an image having a high resolution.

(51) **Int. Cl.**

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**H04N 5/335** (2006.01)  
**H04N 9/68** (2006.01)  
**H04N 9/07** (2006.01)

(52) **U.S. Cl.** ..... **348/315**; 348/275; 348/311;  
348/234; 348/238

(58) **Field of Classification Search** ..... 348/315,  
348/298, 234, 238, 311; 257/72, 294; 250/208.1  
See application file for complete search history.

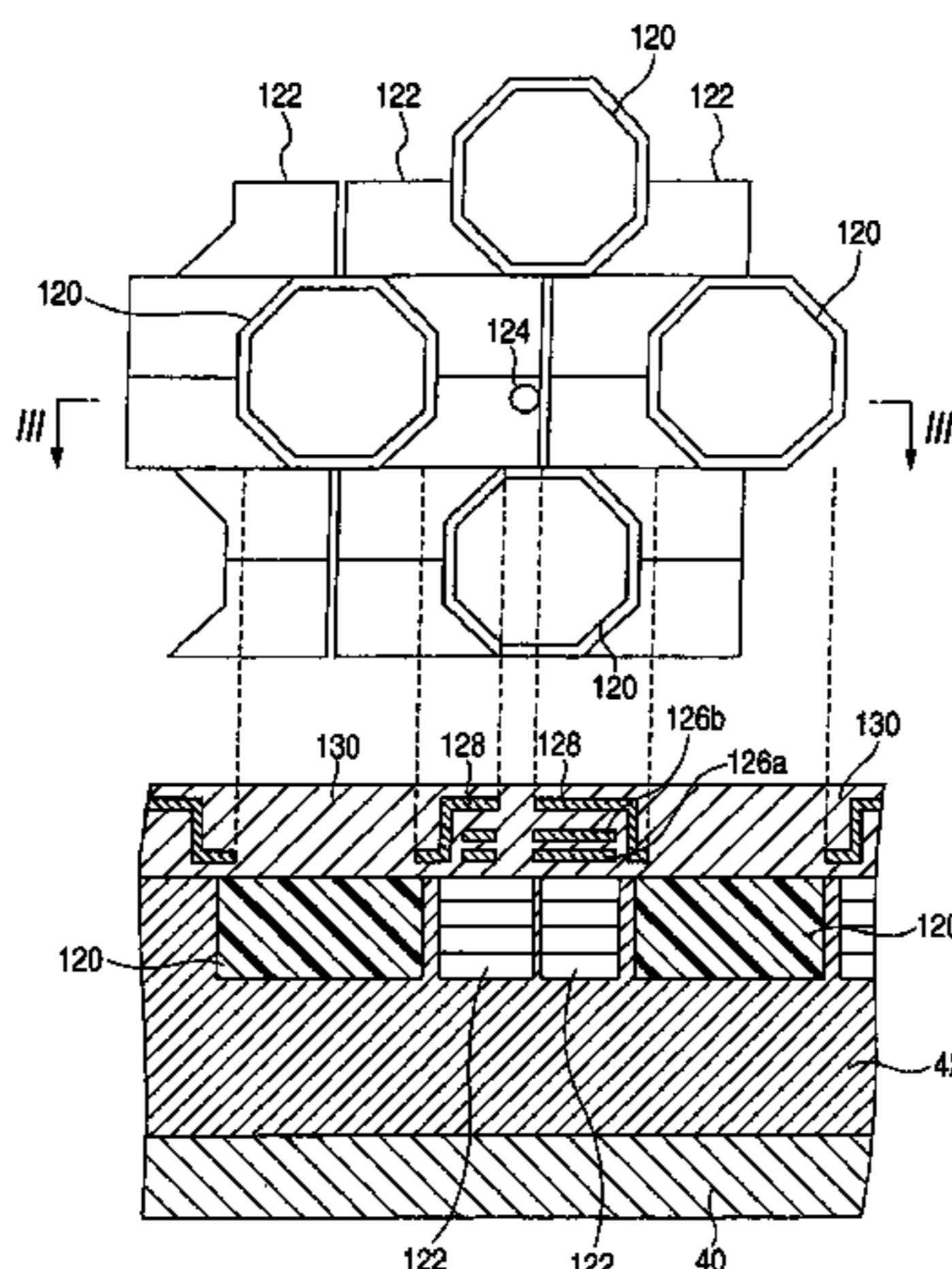
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**19 Claims, 19 Drawing Sheets**



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FIG. 1

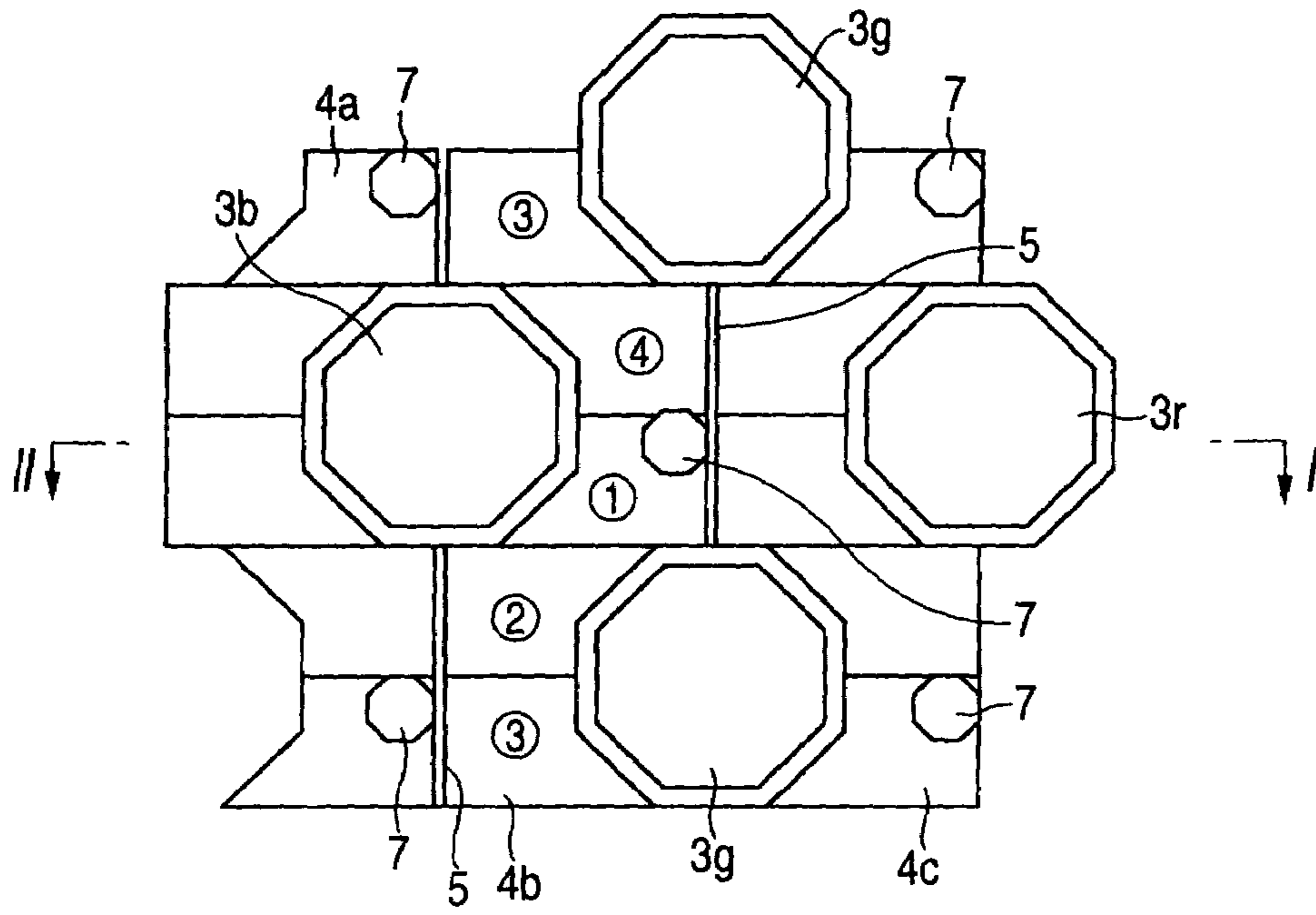


FIG. 2

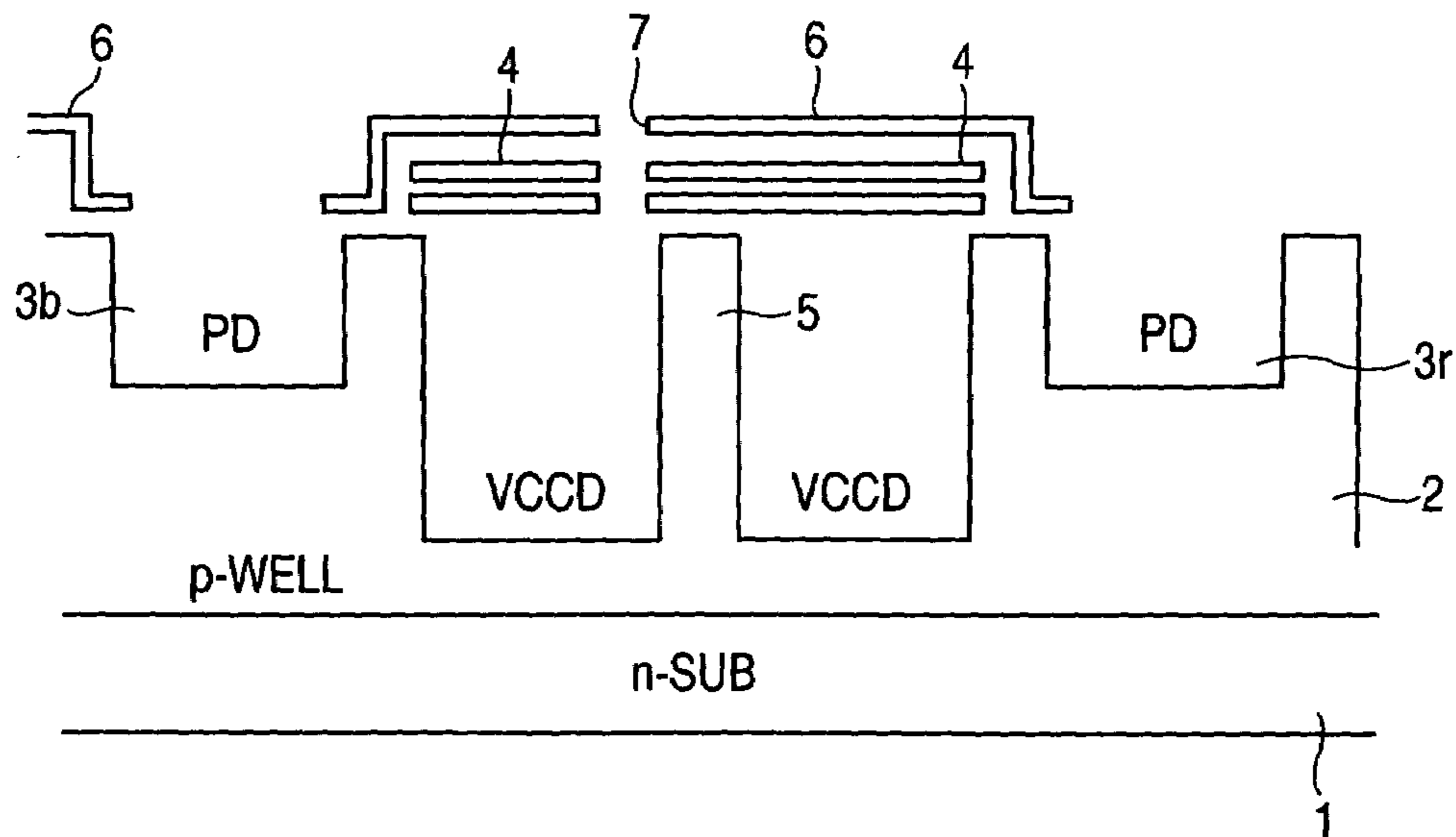


FIG. 3

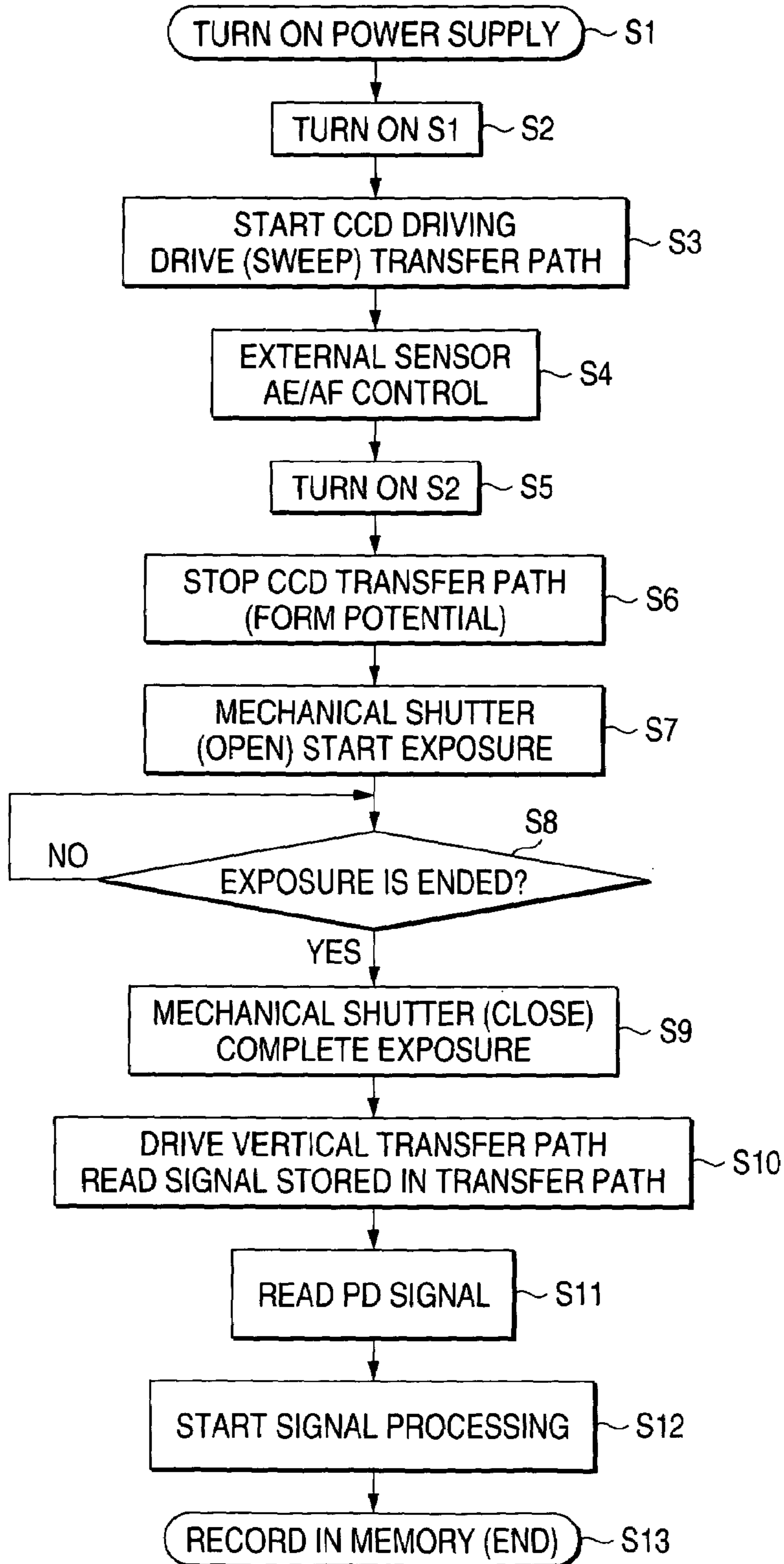


FIG. 4

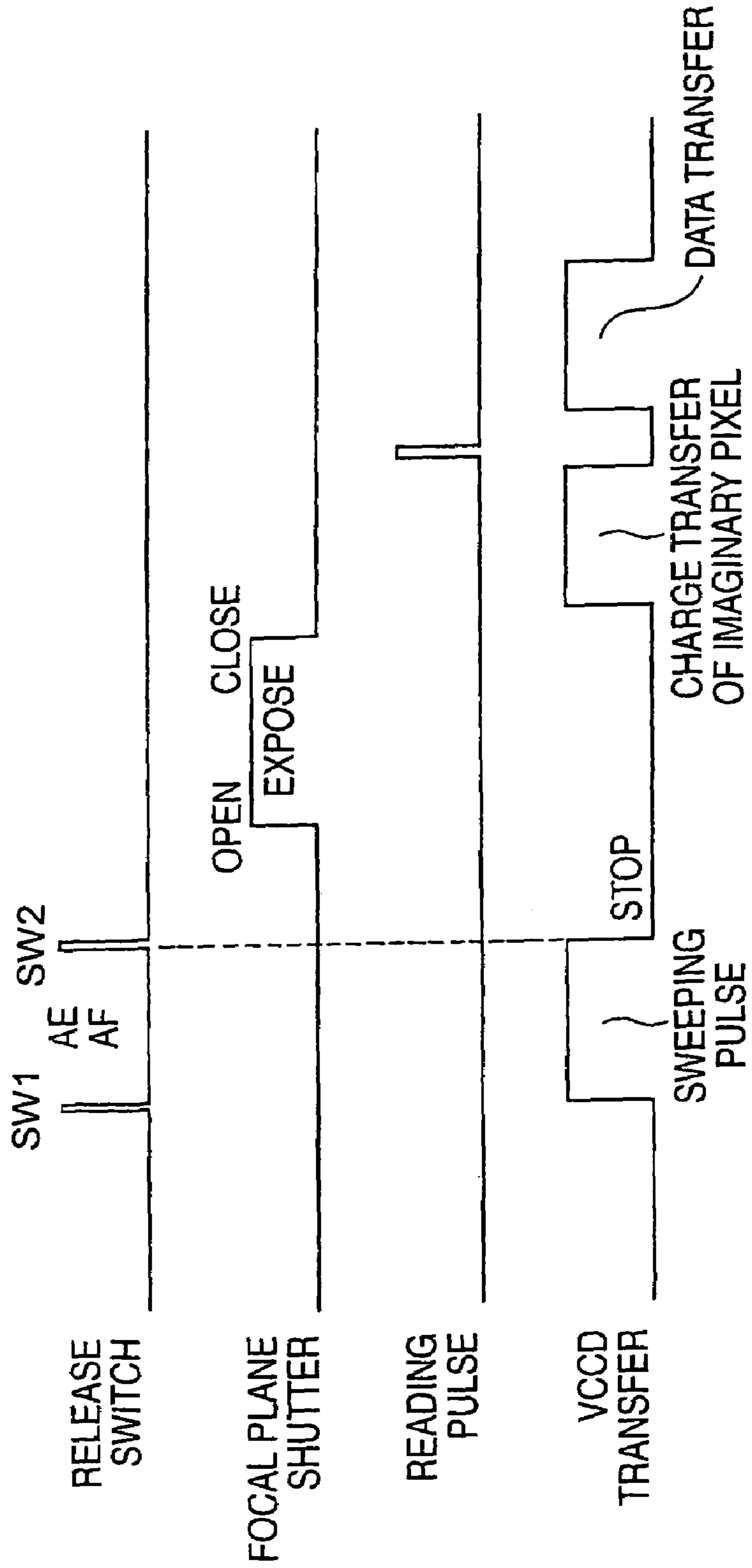


FIG. 5

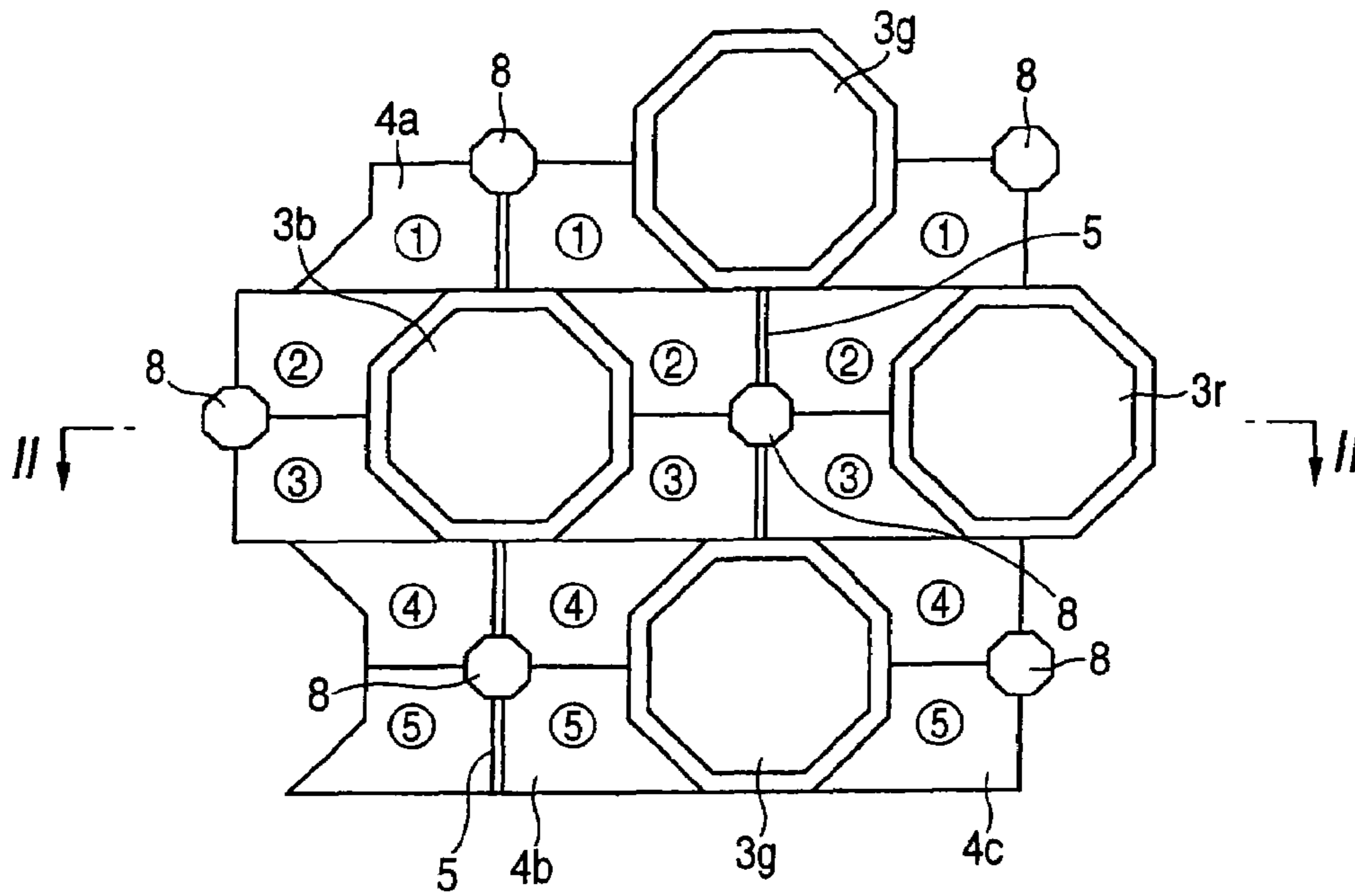
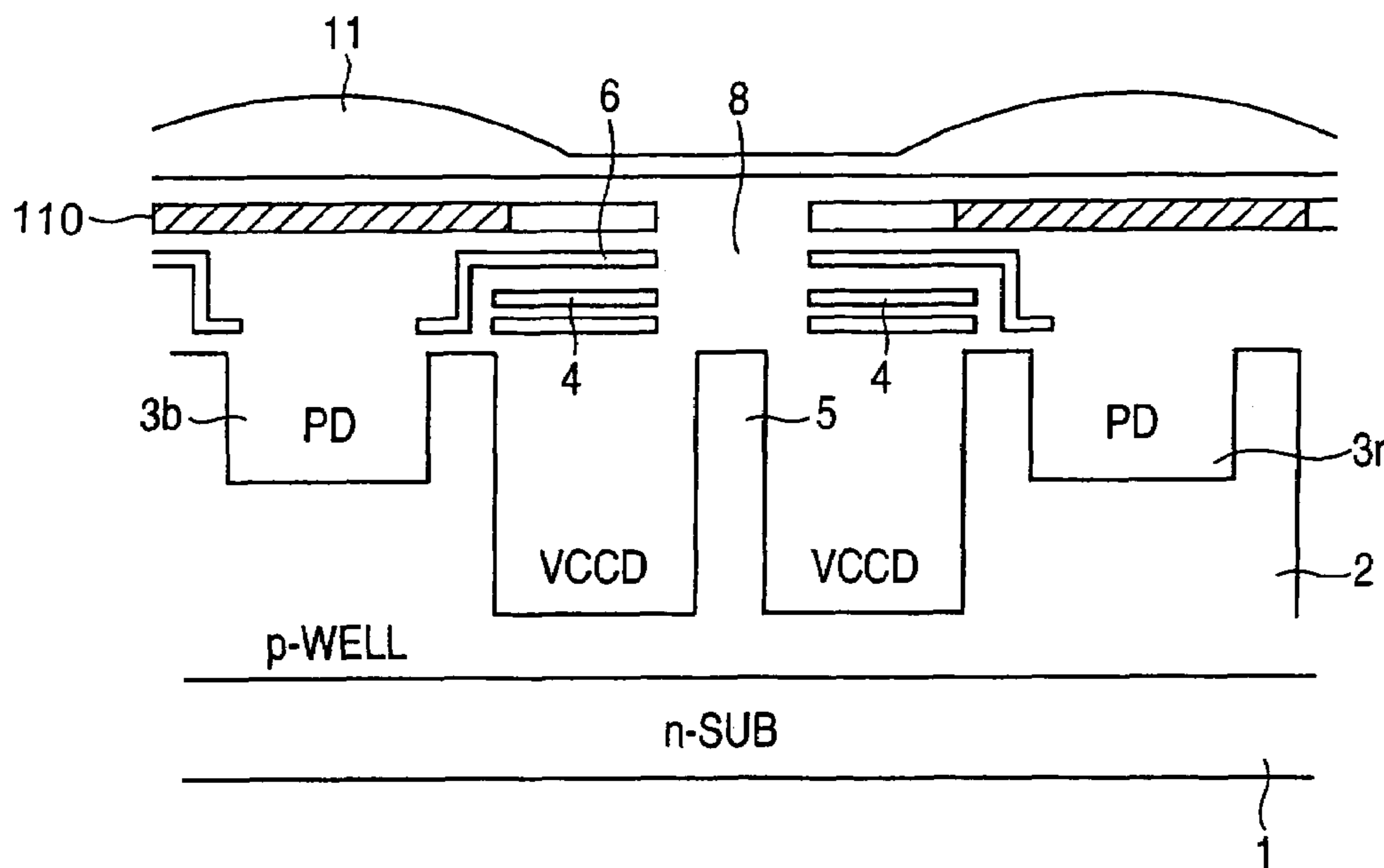
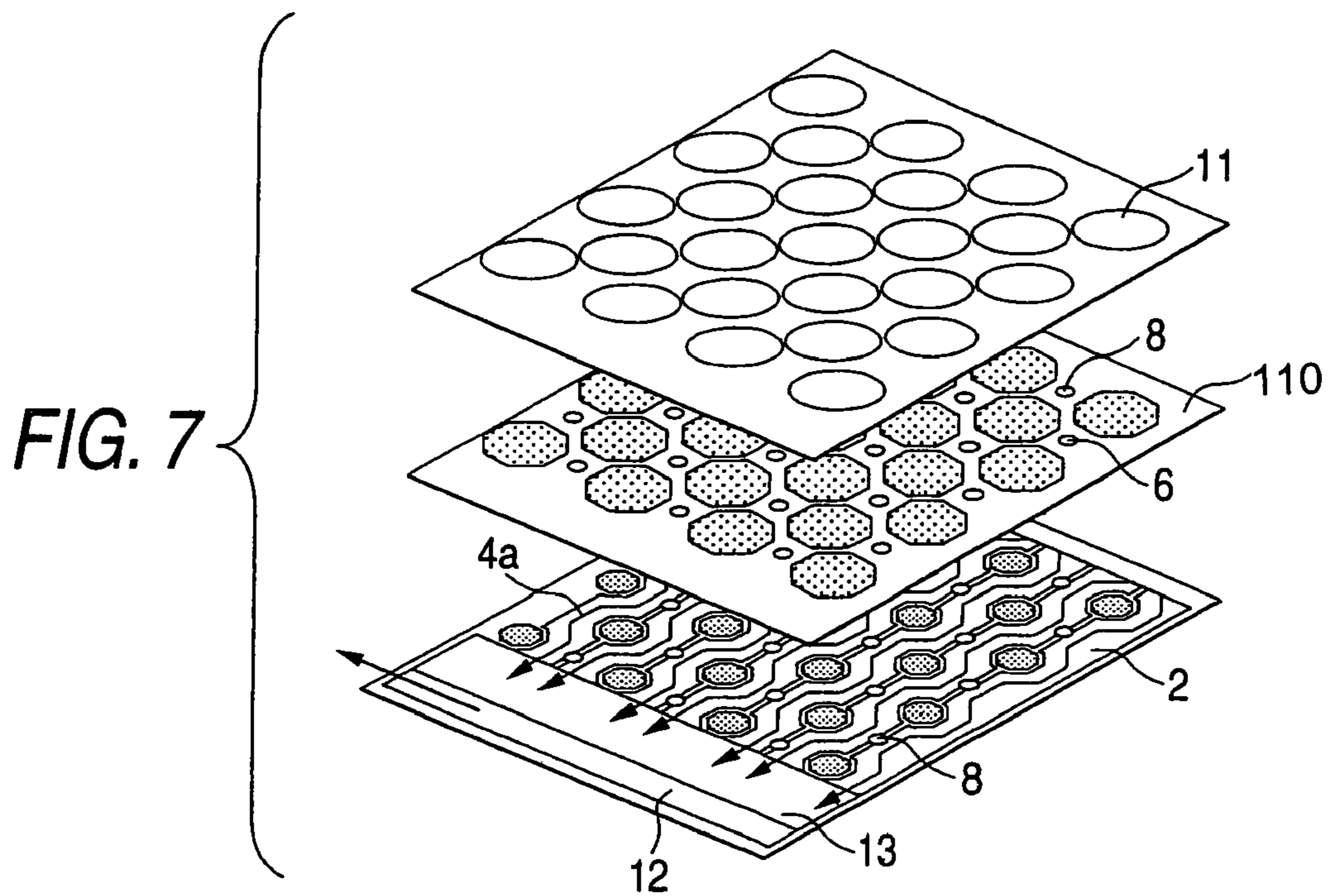


FIG. 6





**FIG. 8**

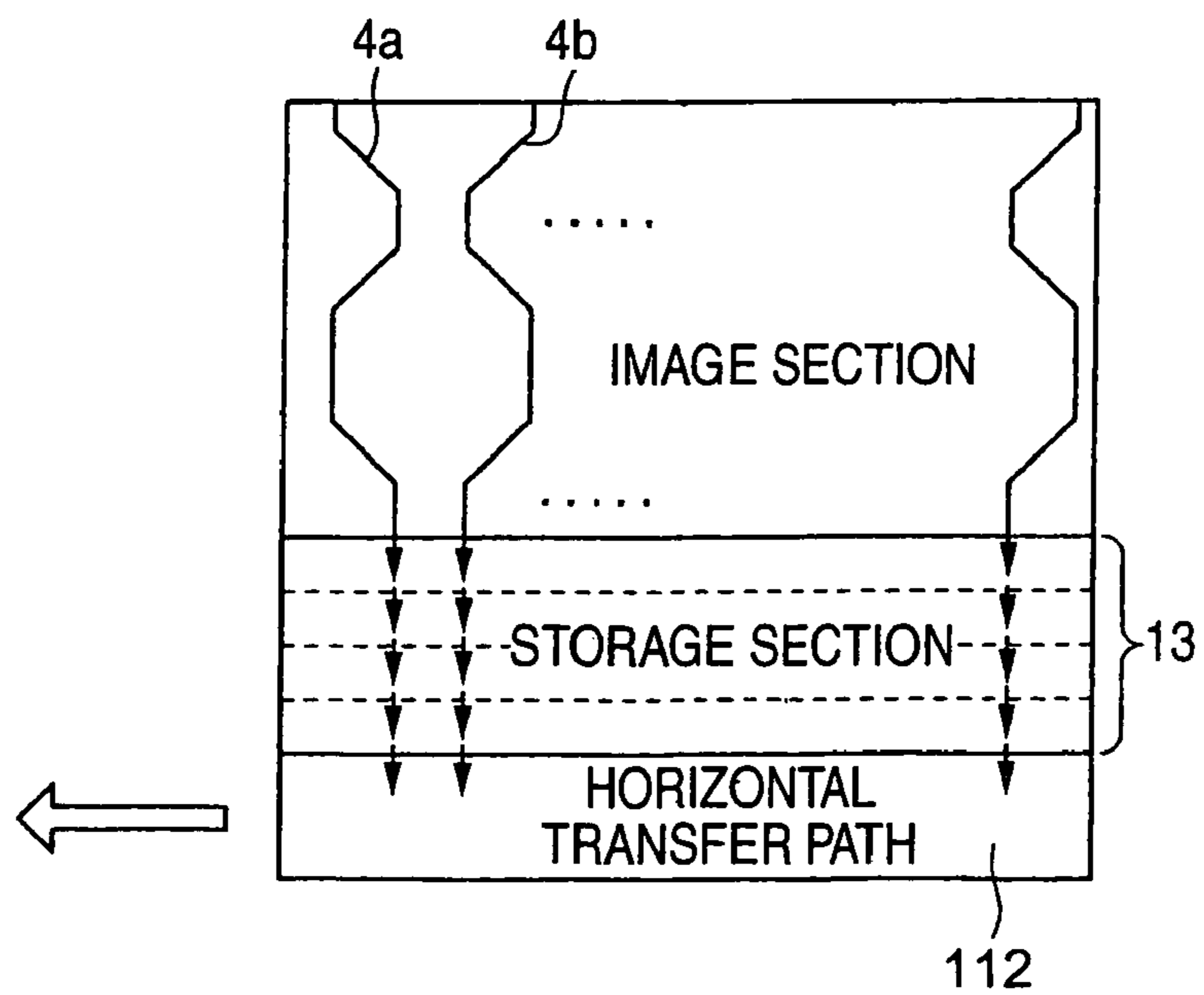


FIG. 9

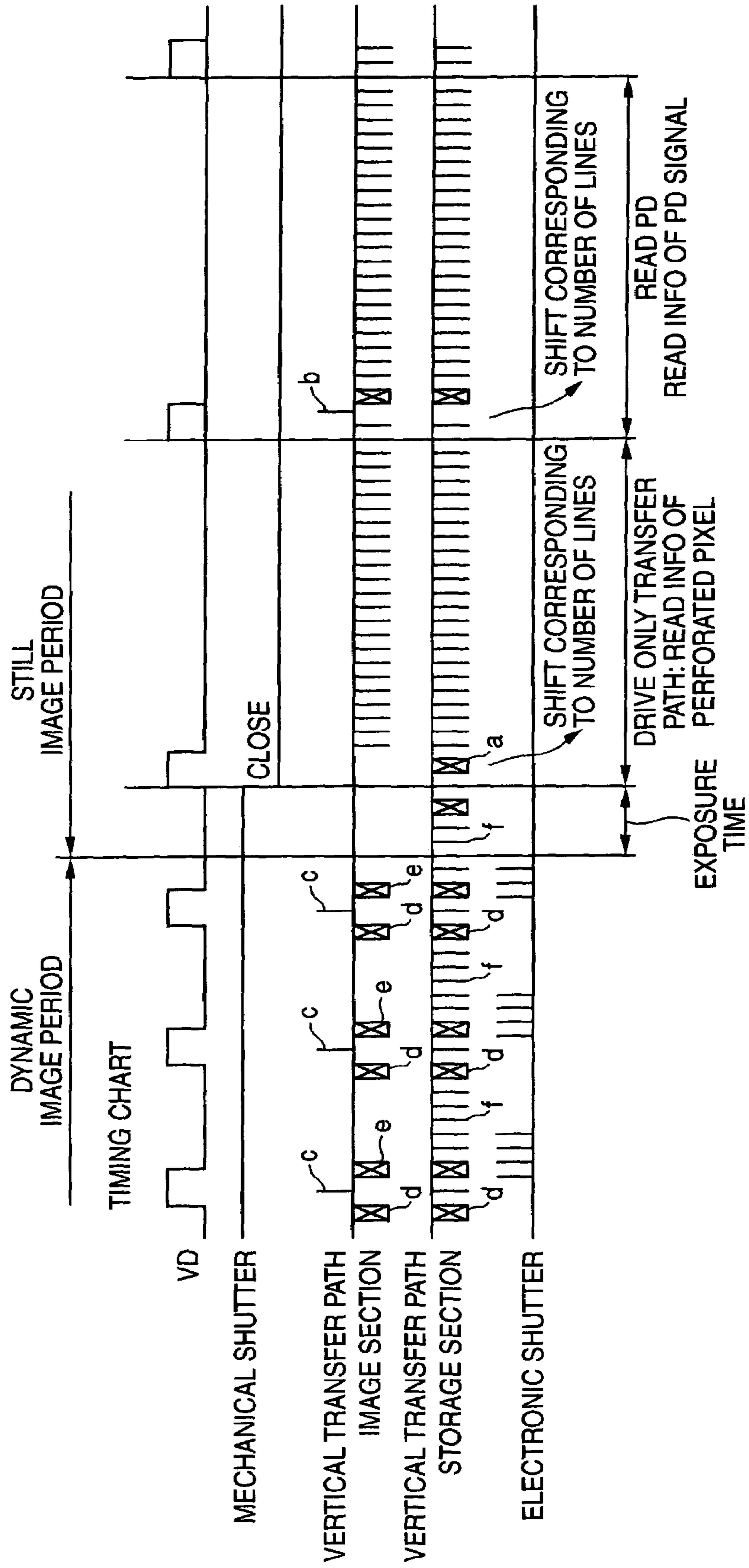




FIG. 10

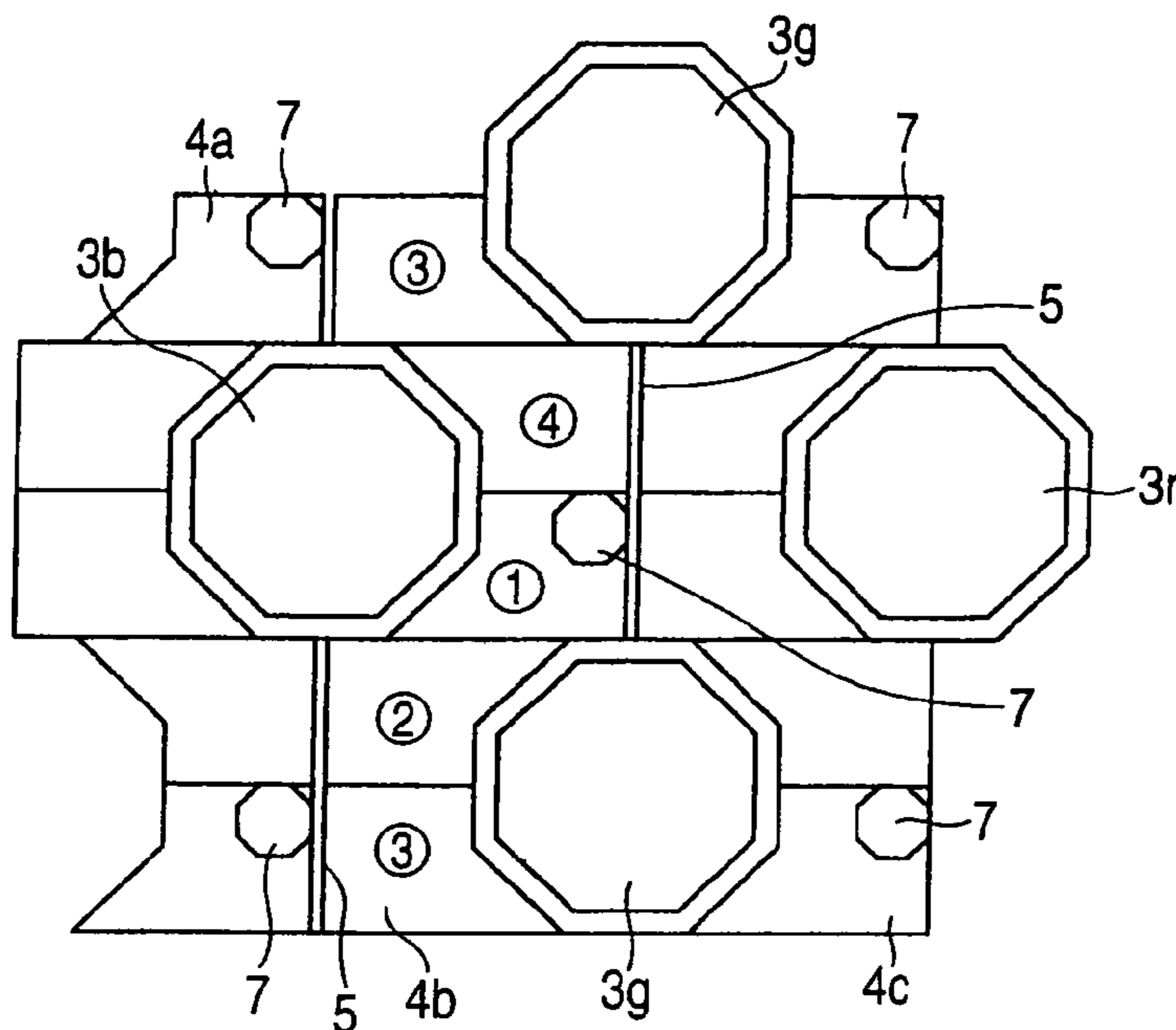
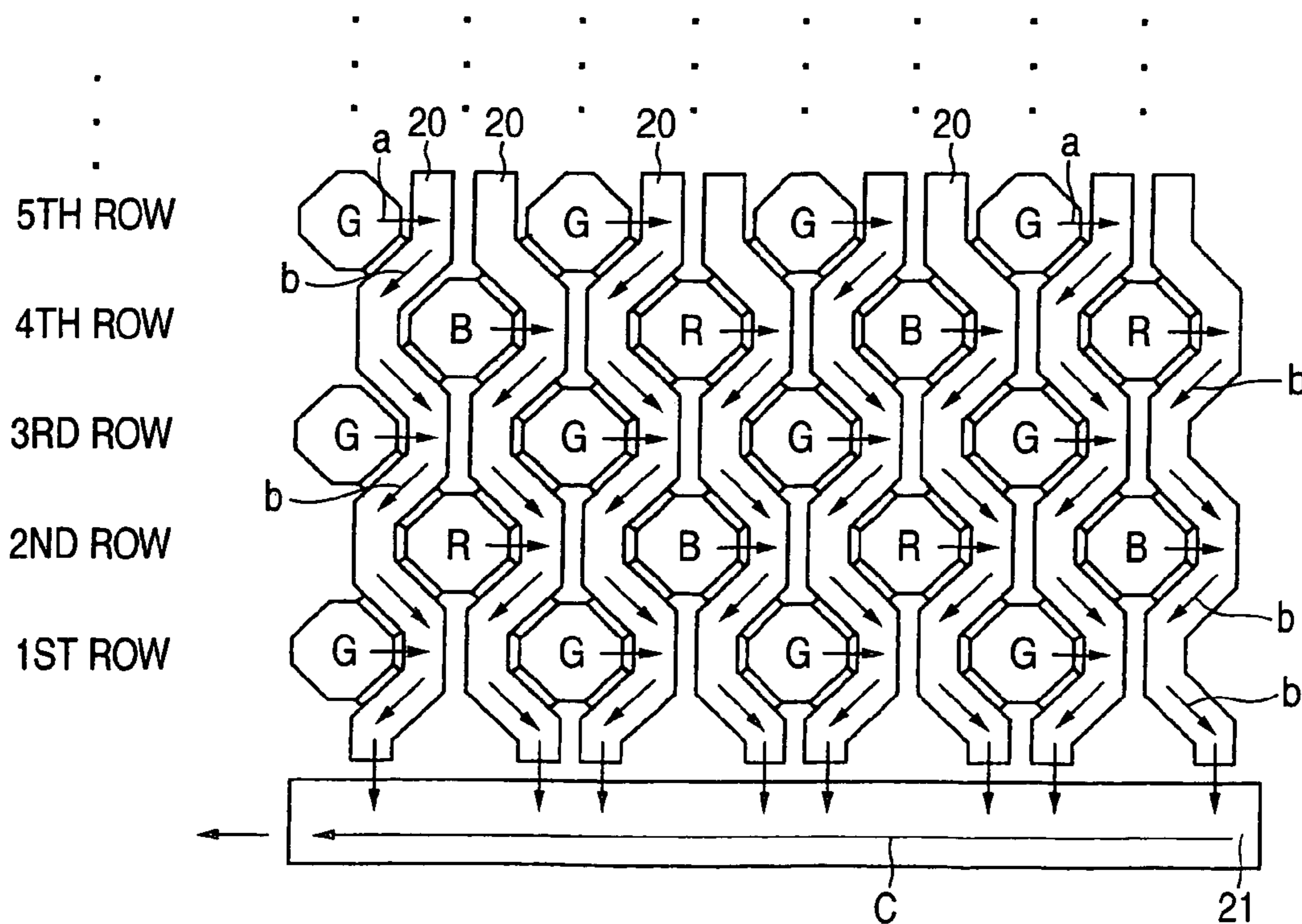
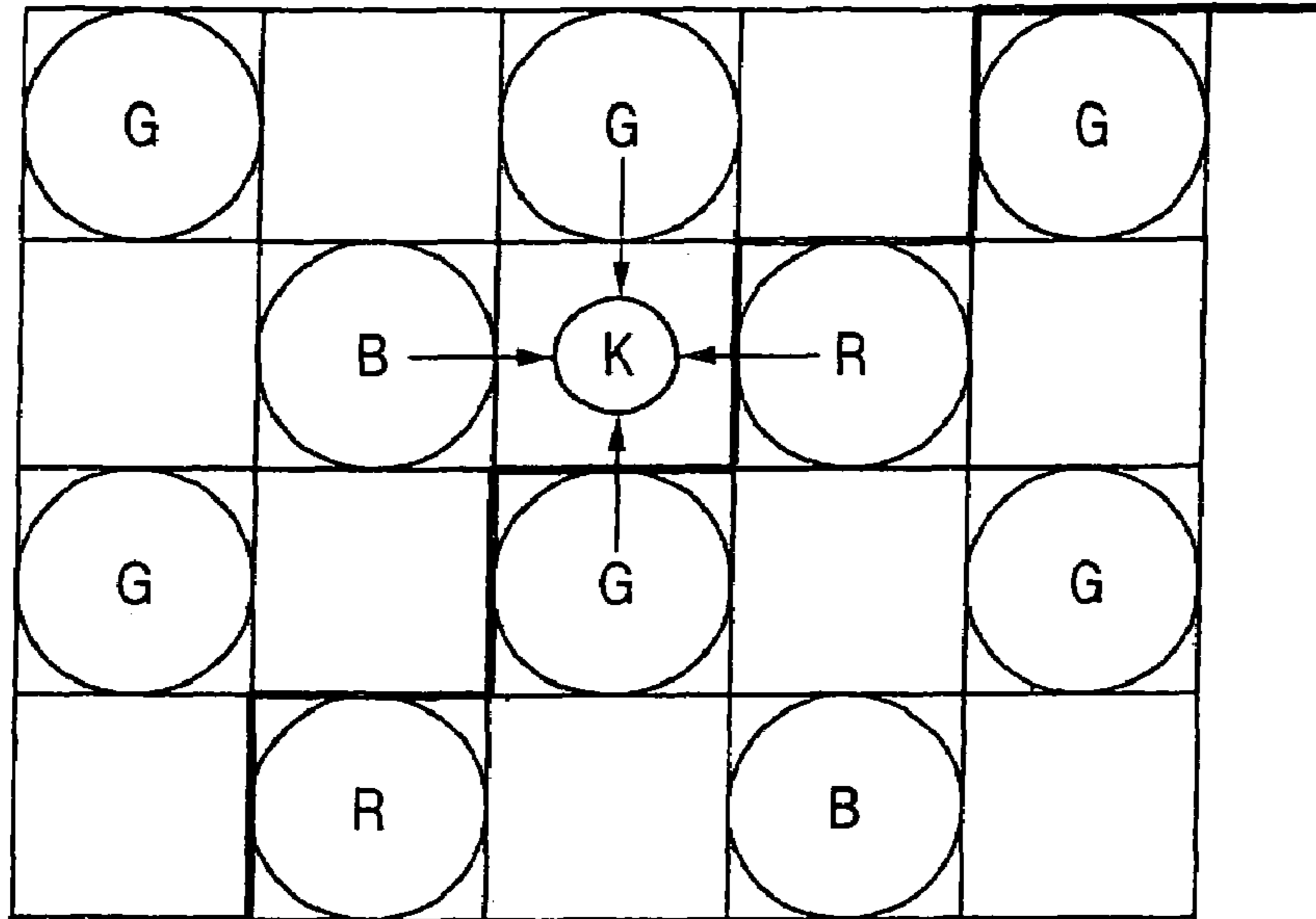


FIG. 11 PRIOR ART



*FIG. 12 (a)* PRIOR ART



*FIG. 12 (b)*

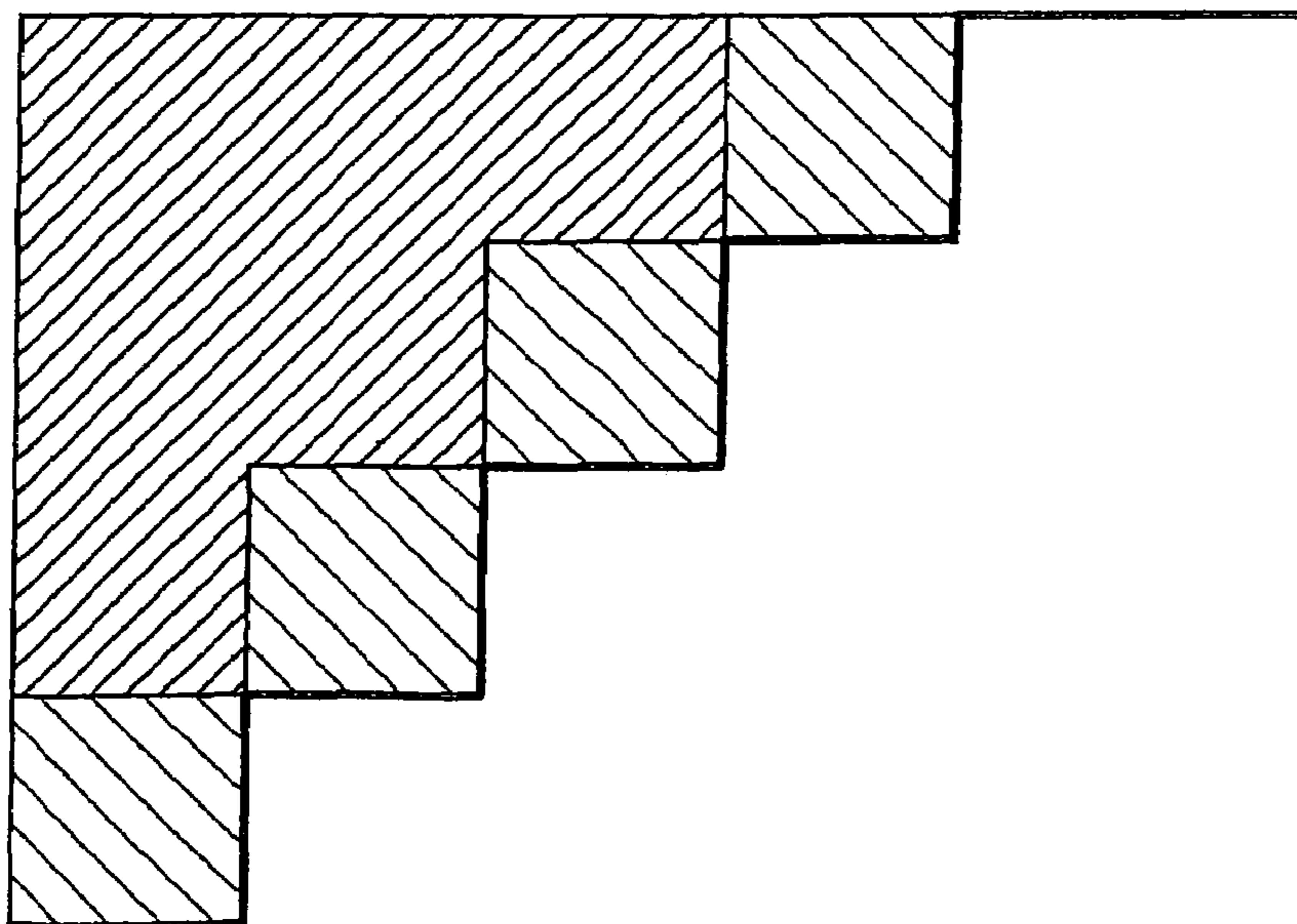


FIG. 13

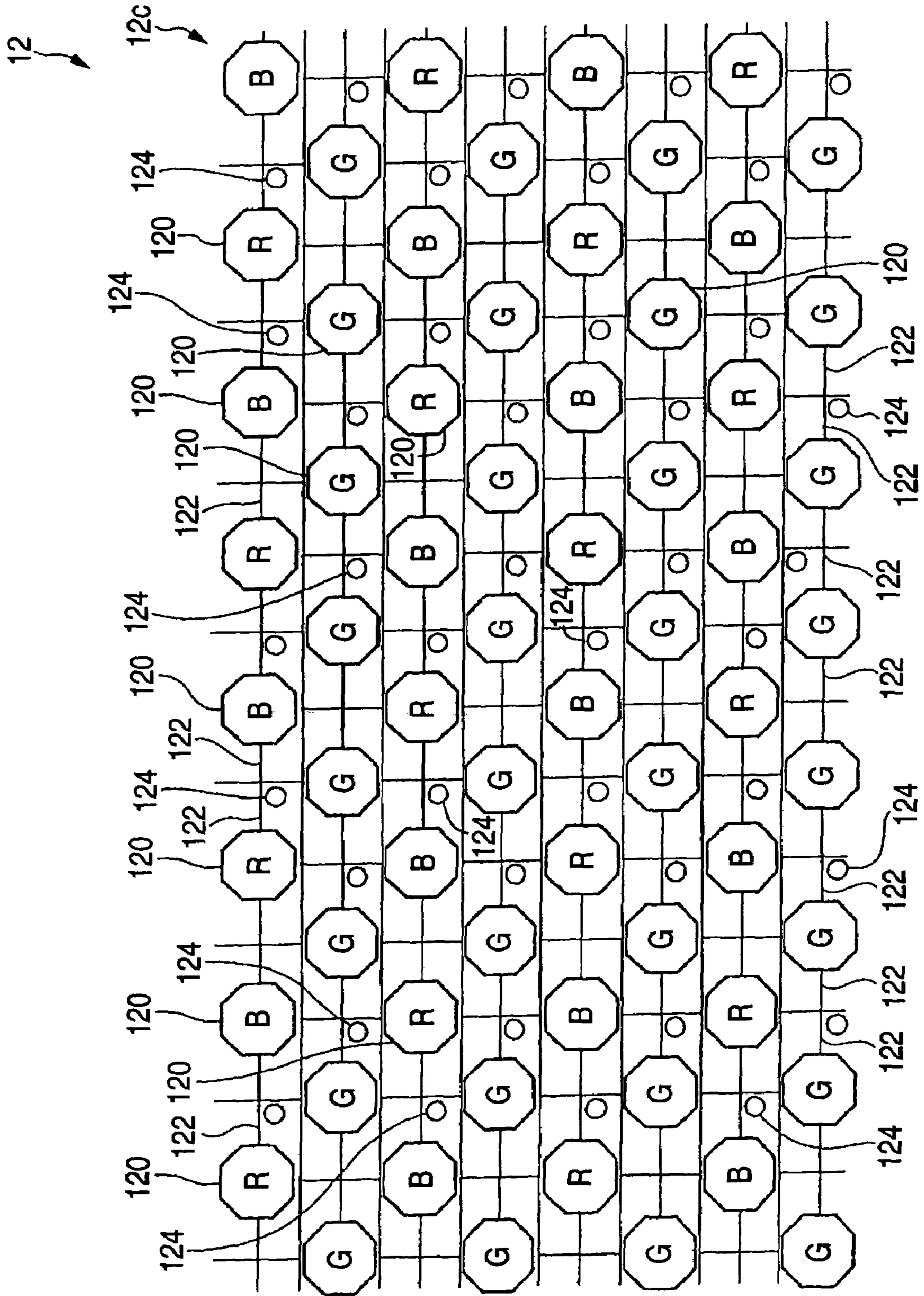


FIG. 14

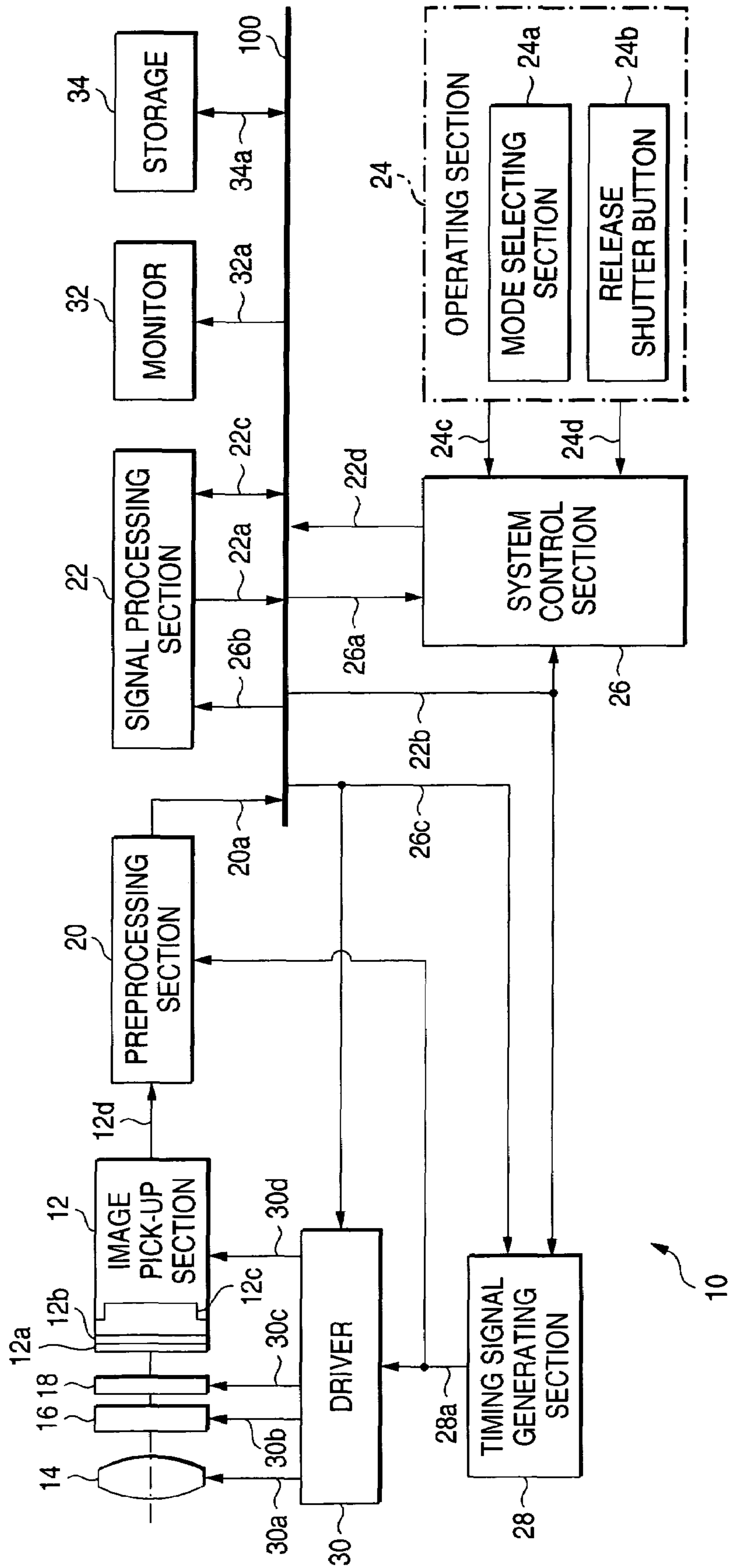


FIG. 15

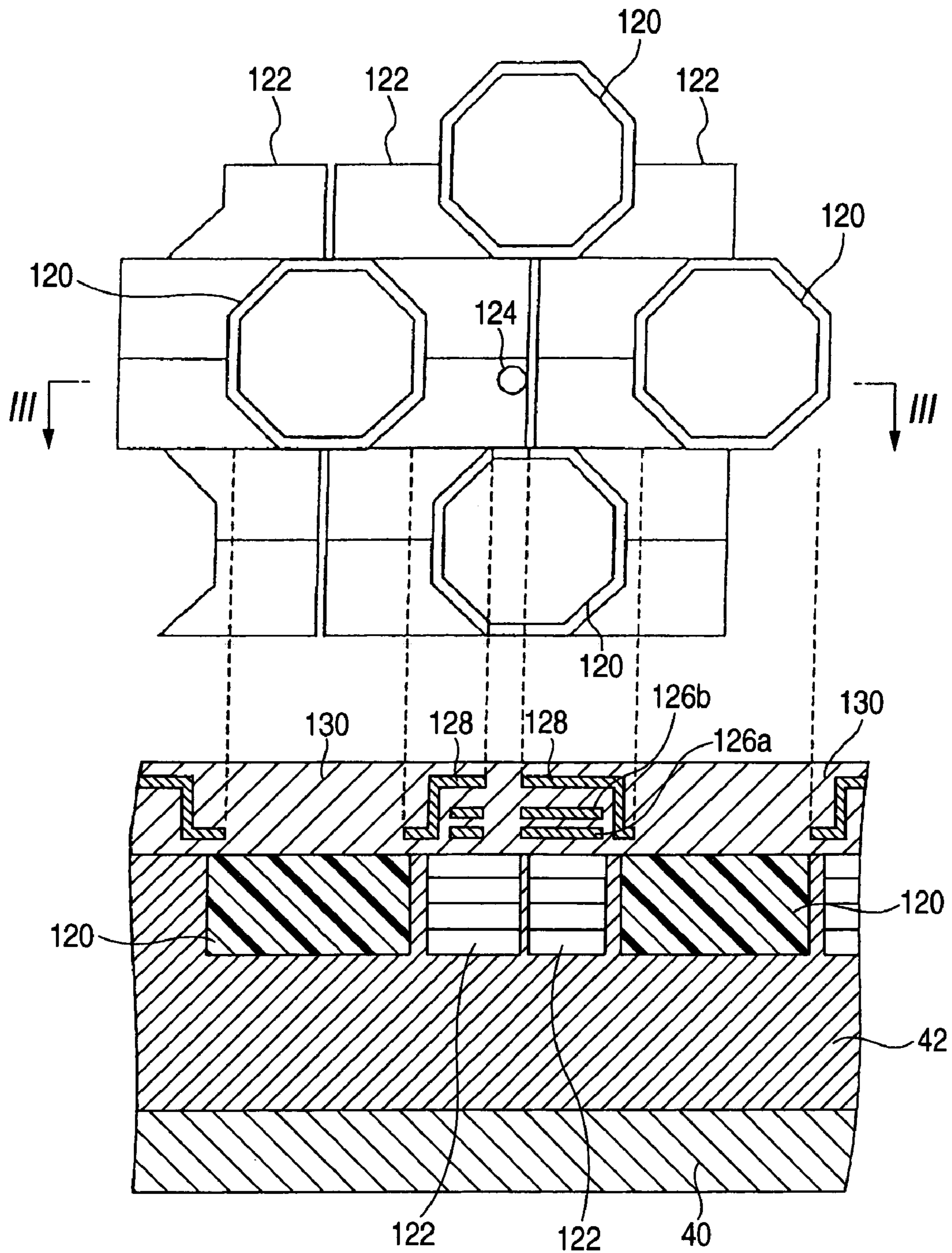


FIG. 16

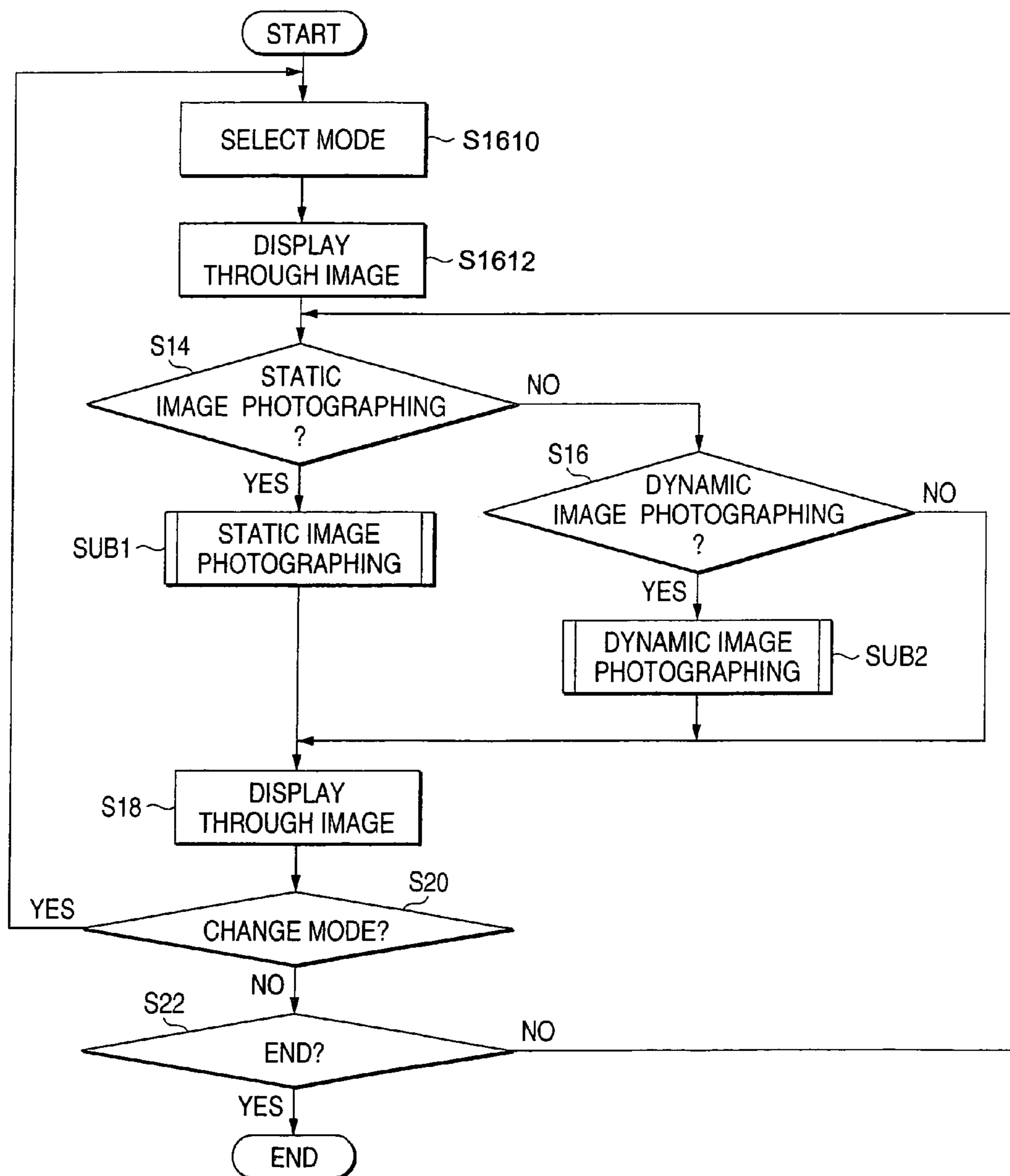


FIG. 17

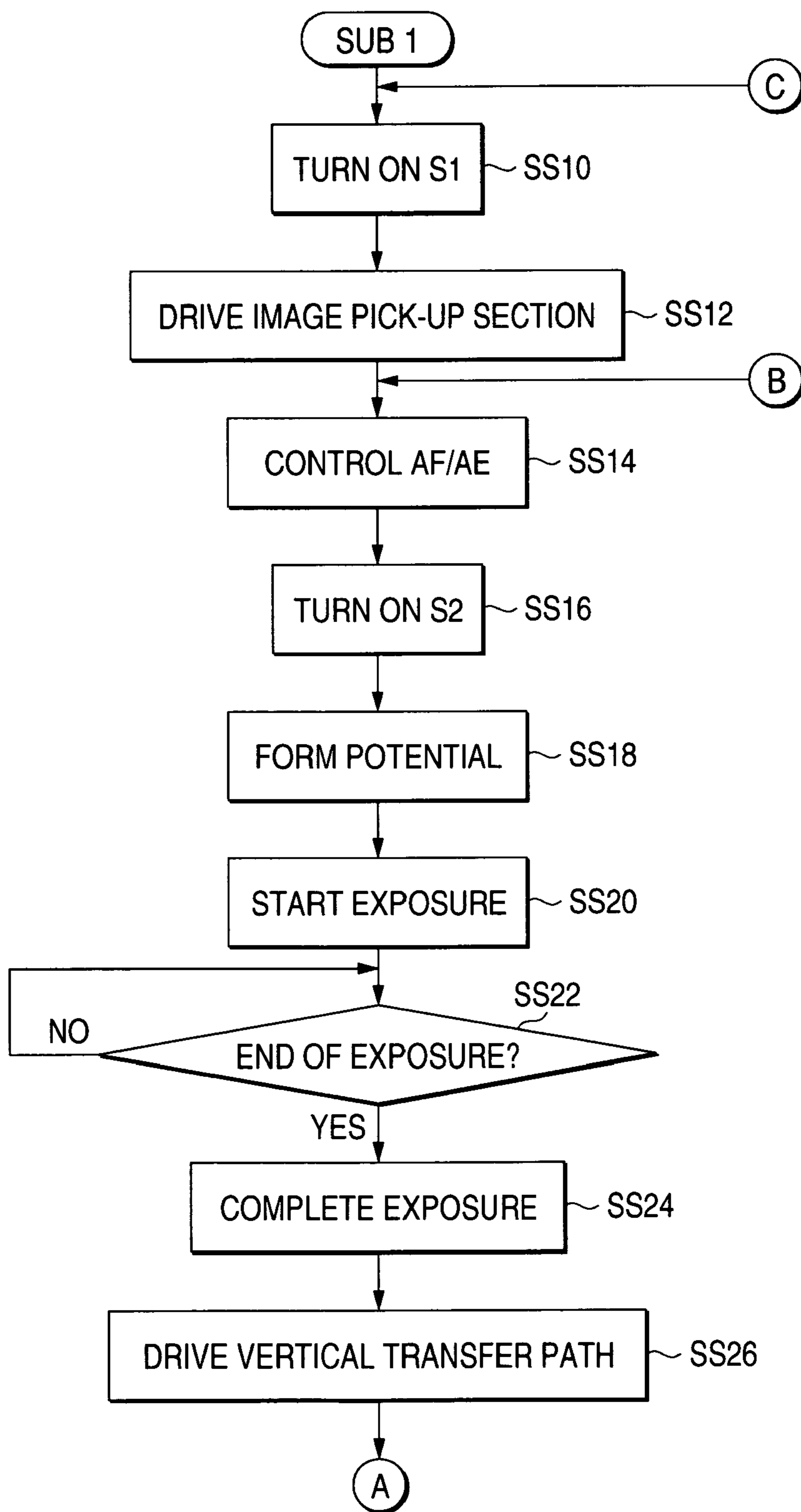


FIG. 18

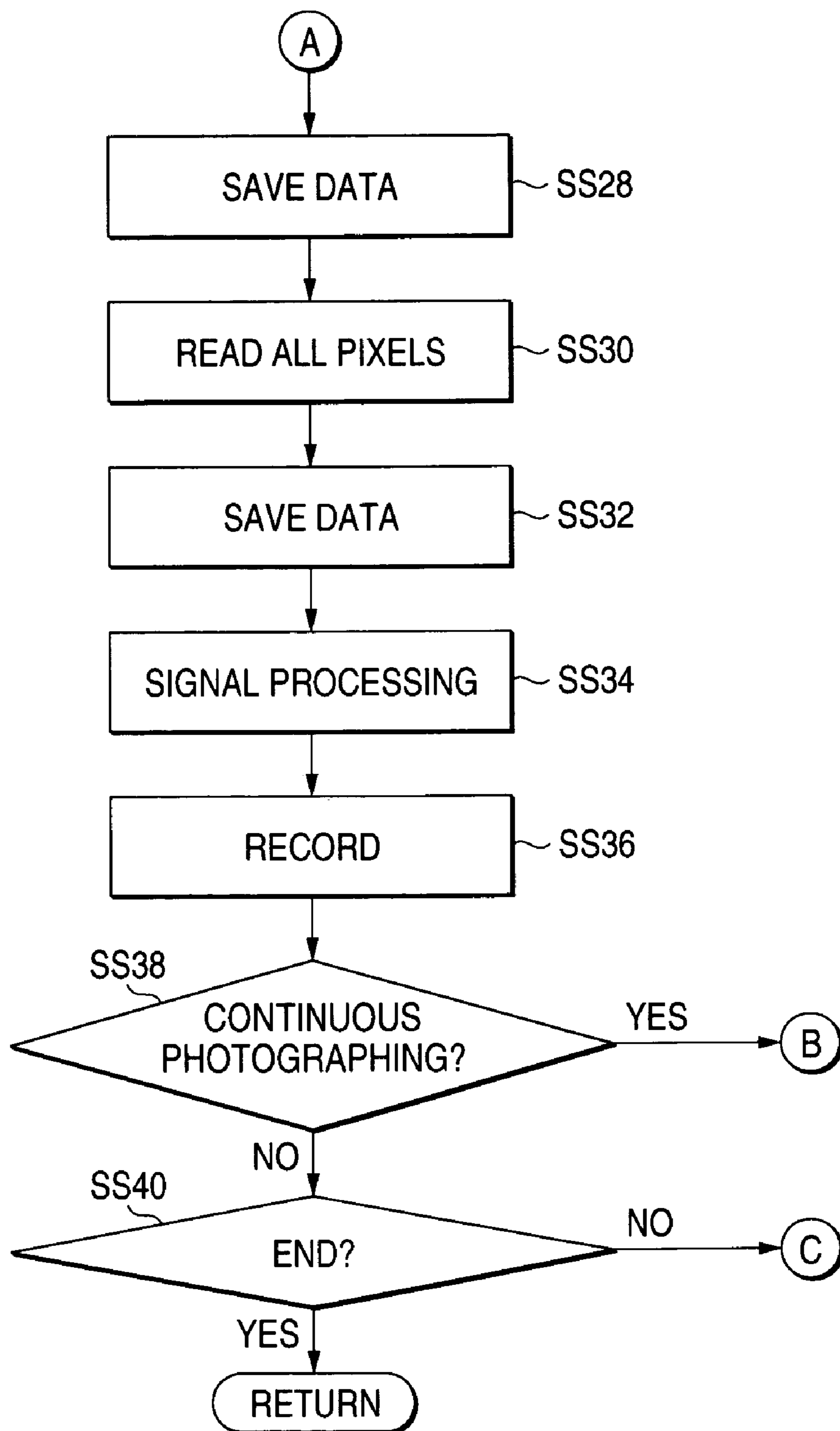




FIG. 19 (a)

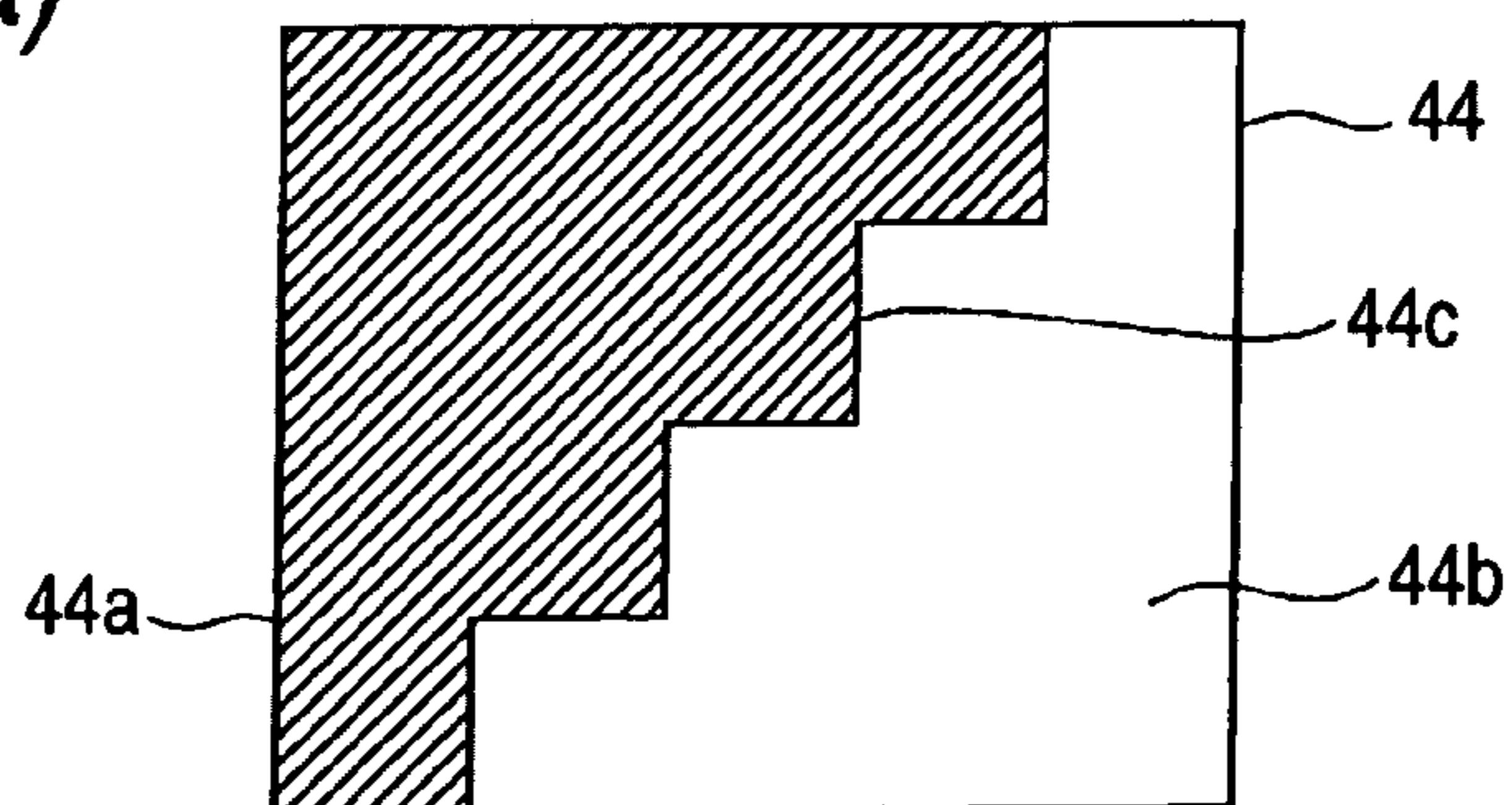


FIG. 19 (b)

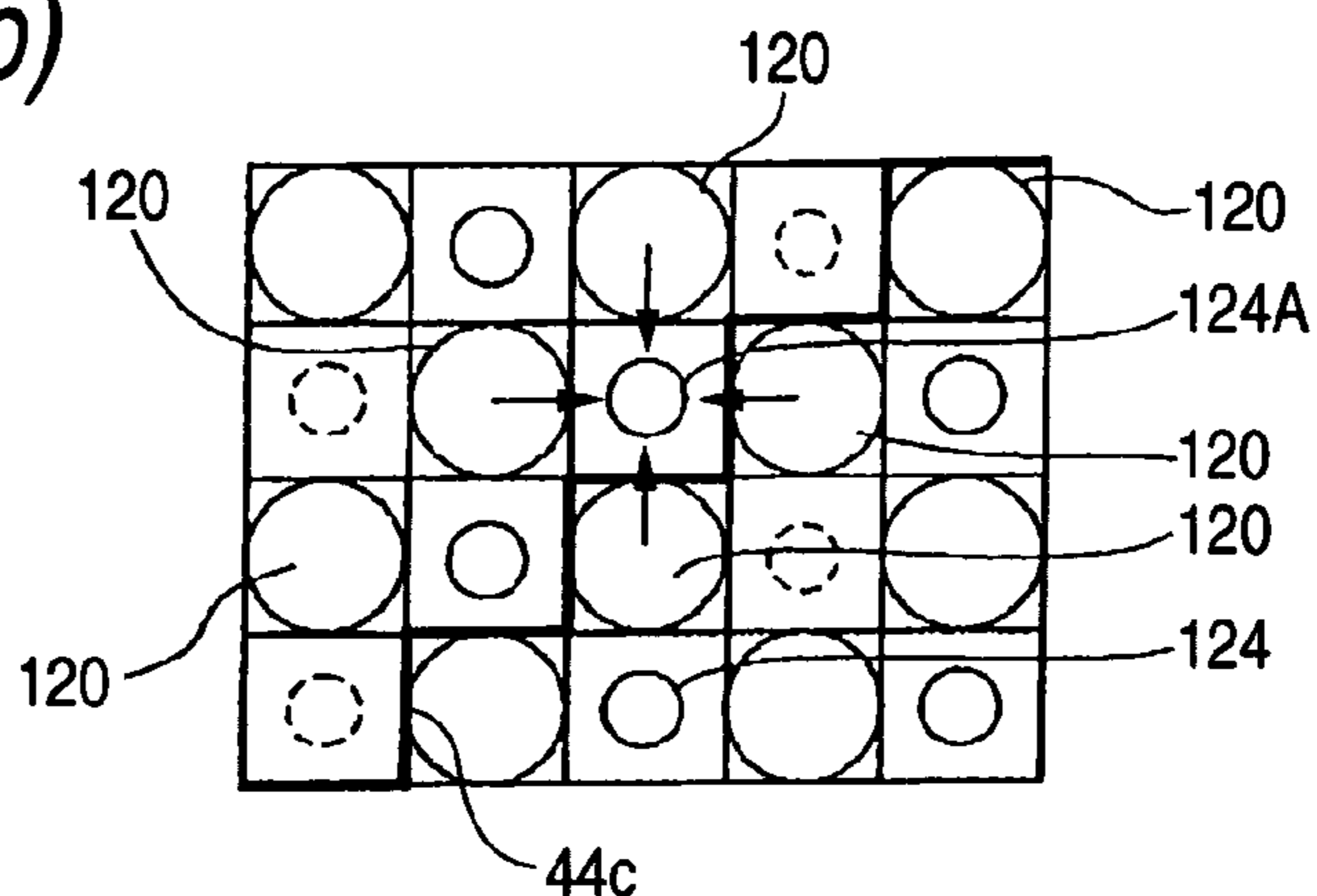


FIG. 19 (c)

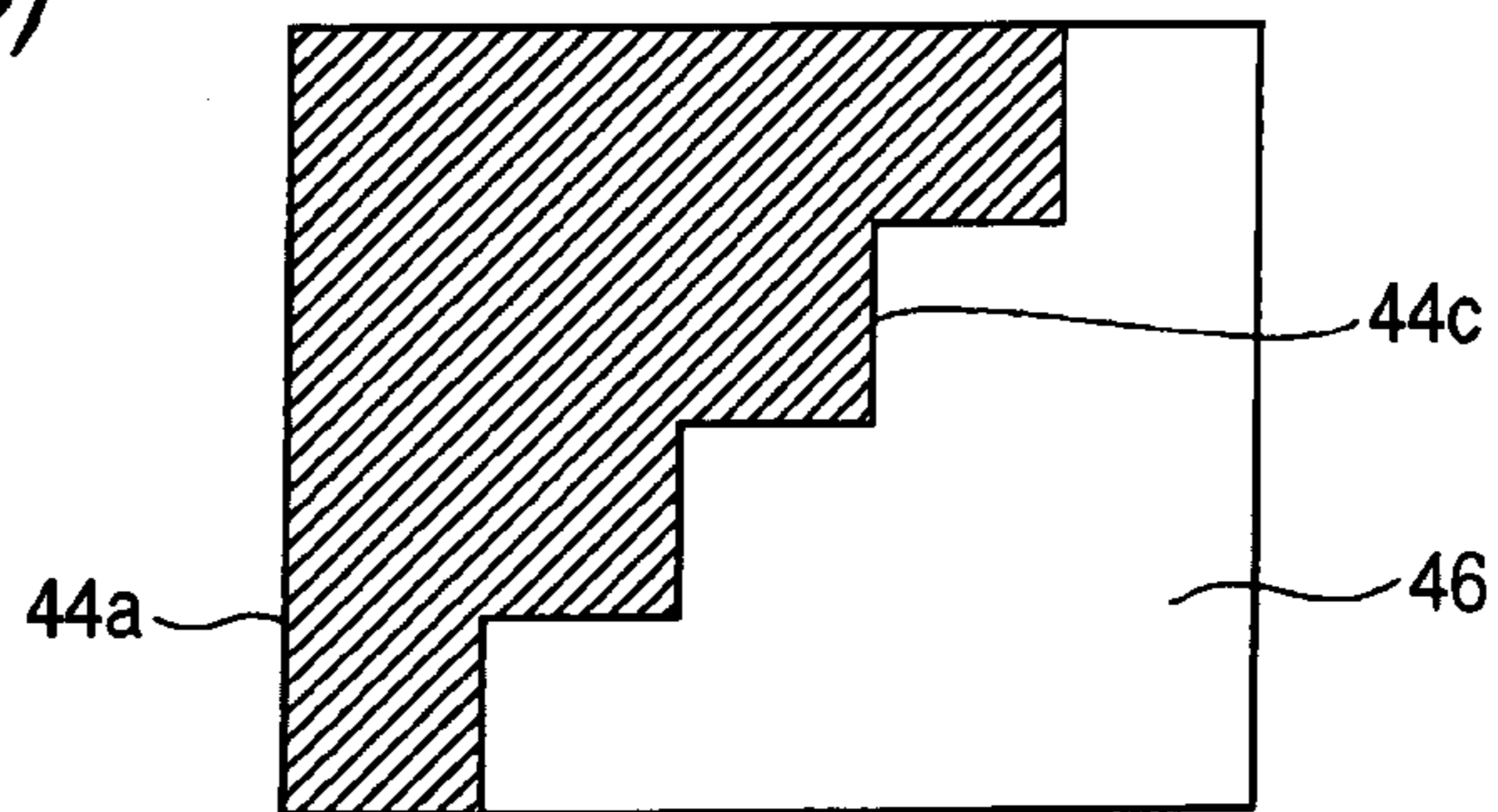


FIG. 19 (d)

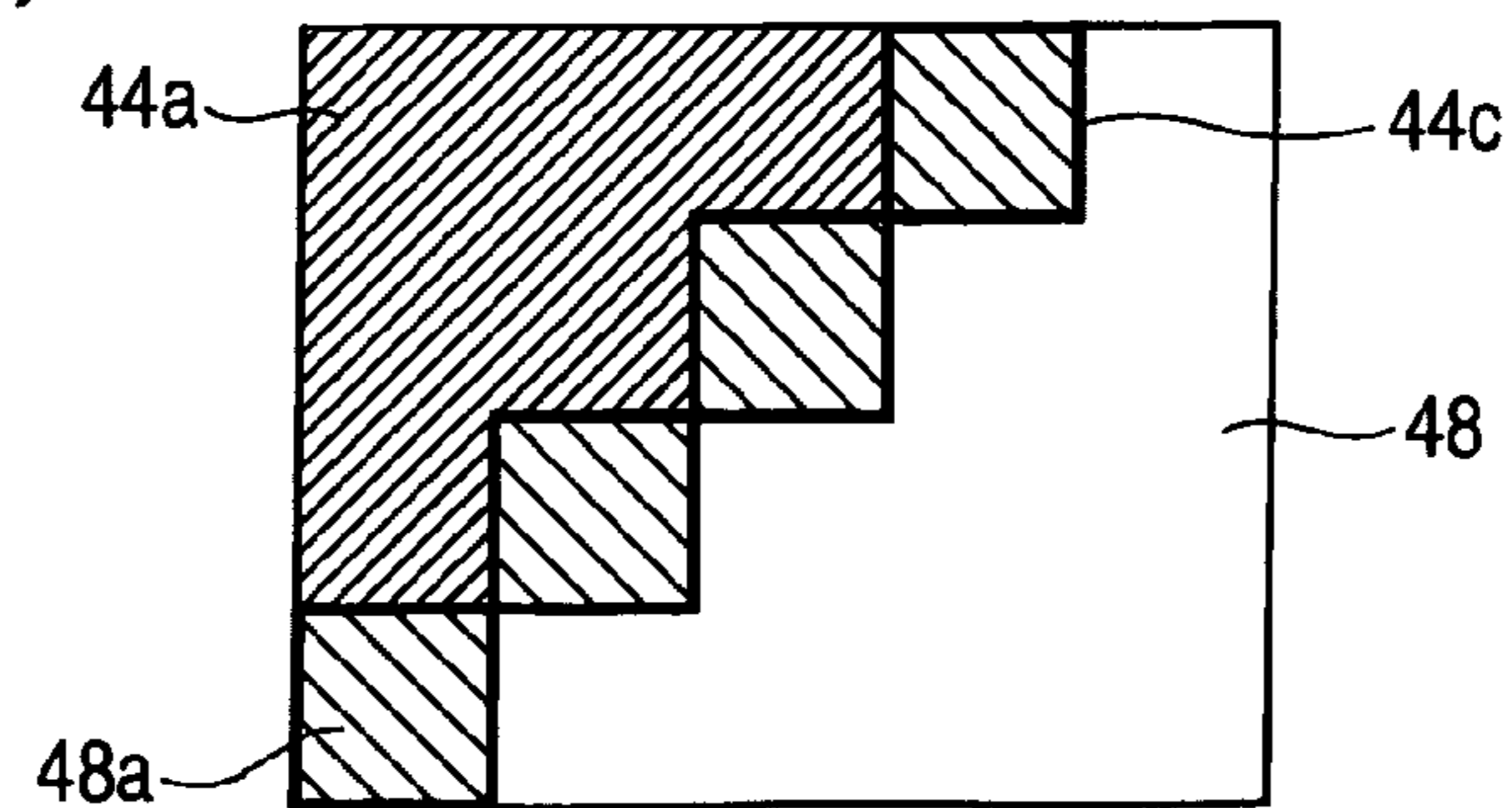


FIG. 20

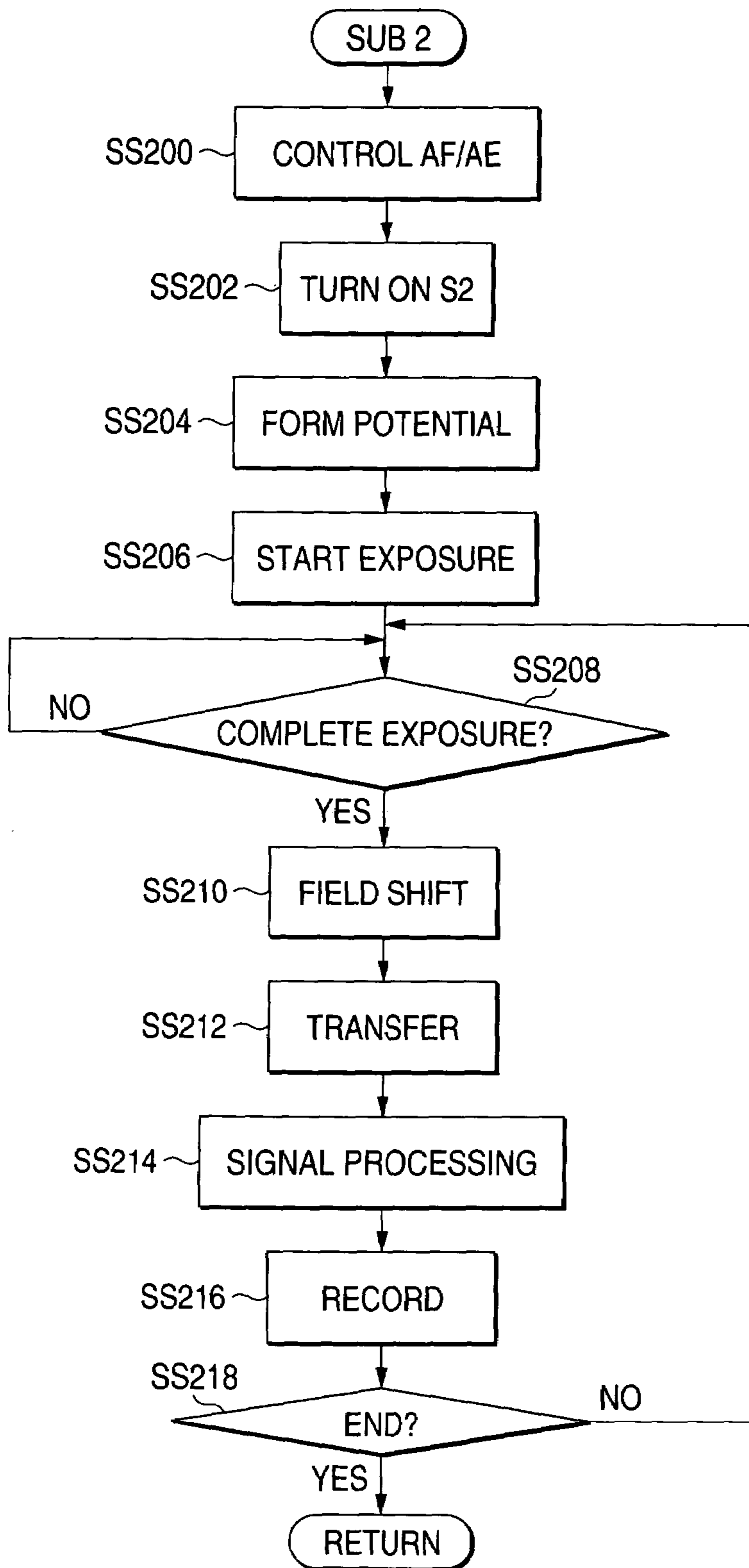


FIG. 21

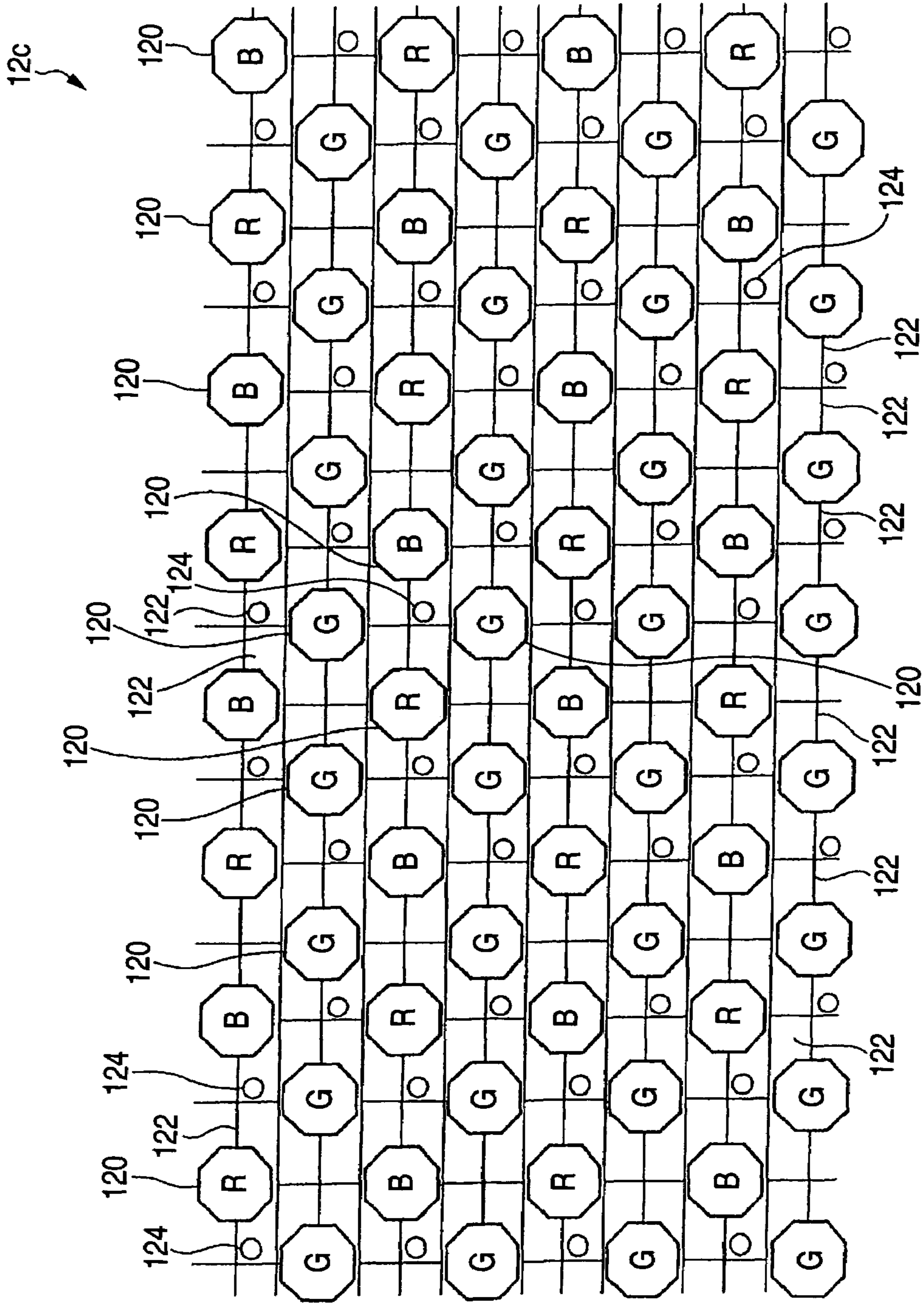


FIG. 22

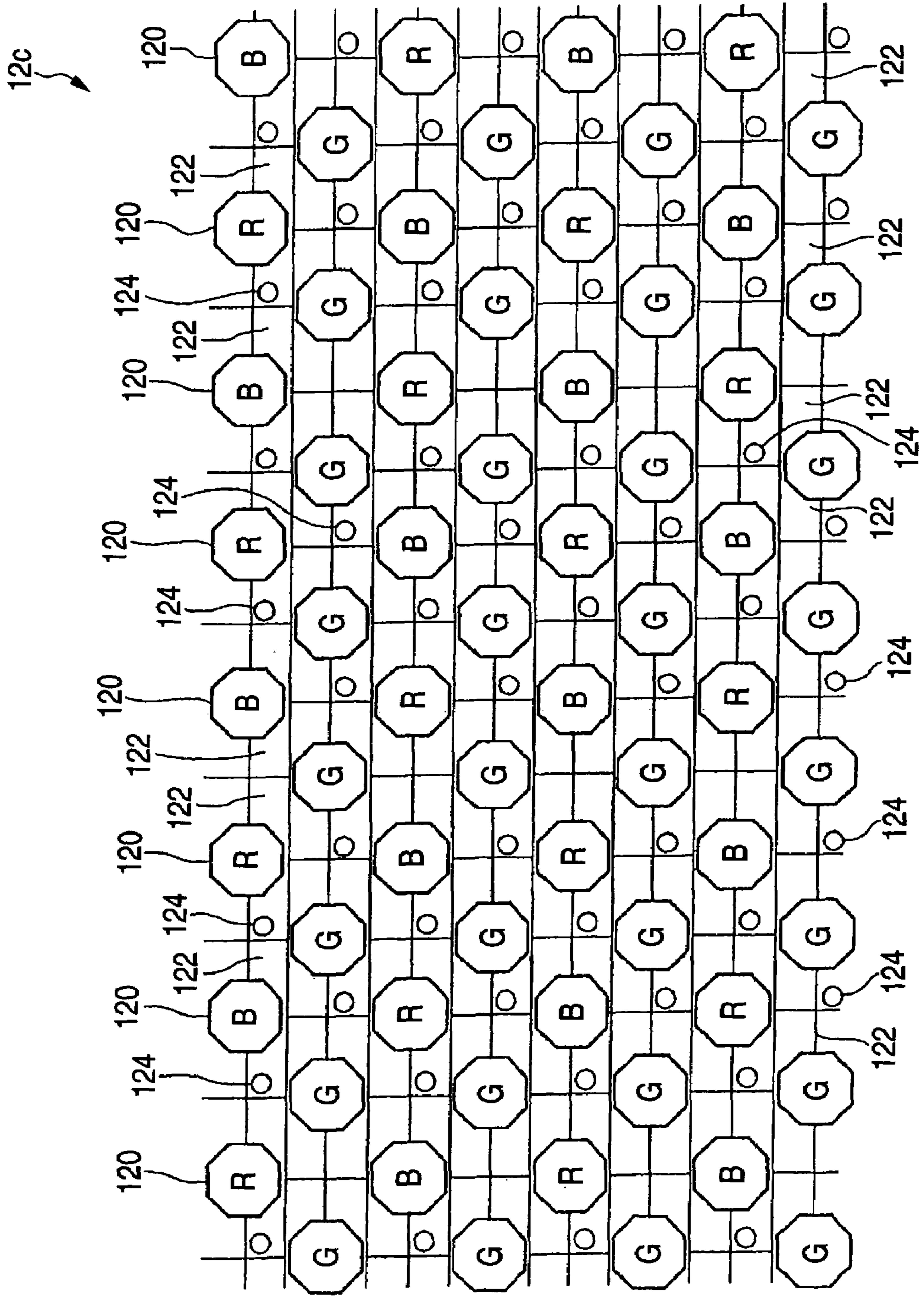
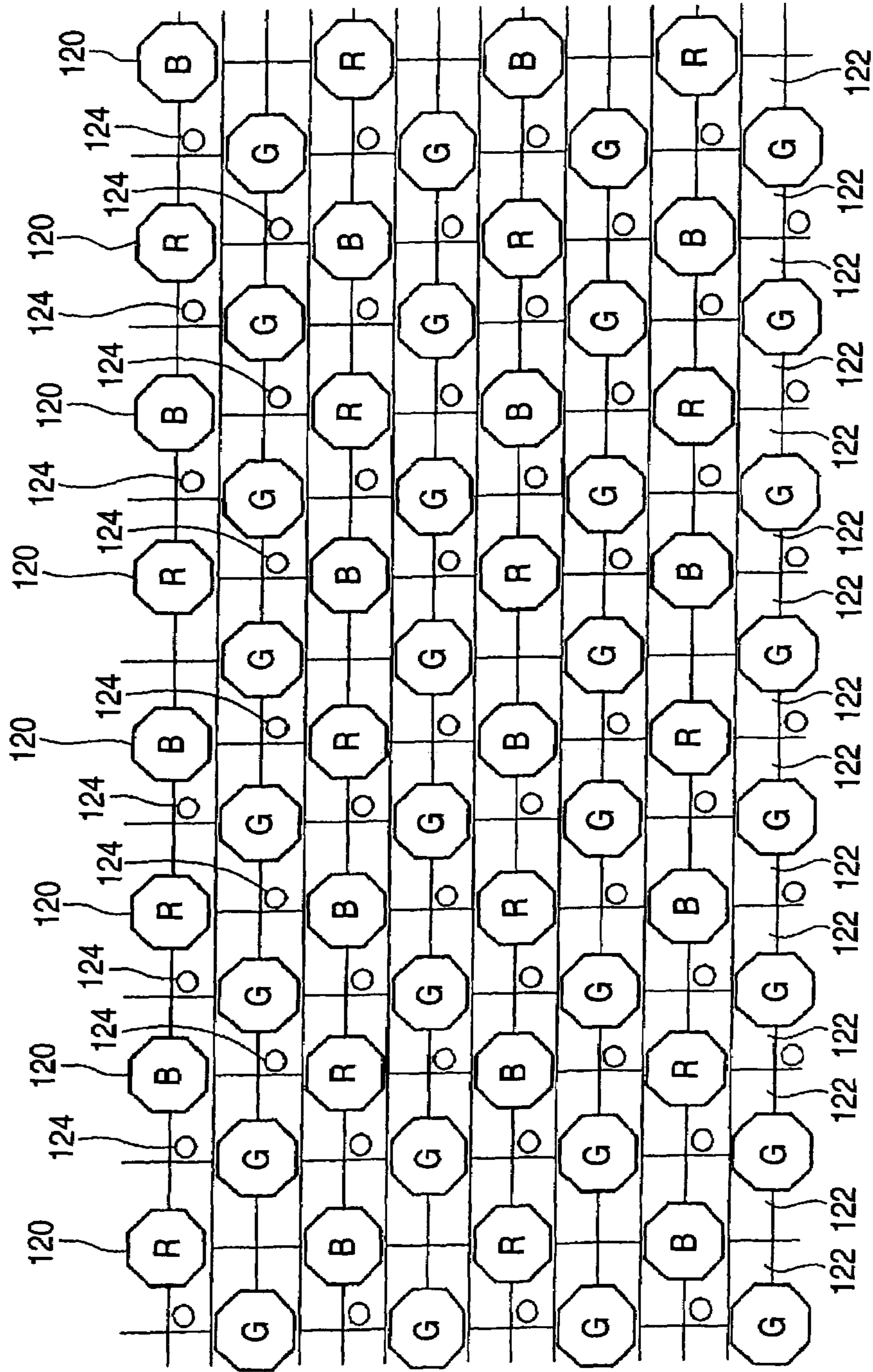


FIG. 23



## SOLID-STATE IMAGE PICK-UP DEVICE AND DIGITAL STILL CAMERA

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to a solid-state image pick-up device, so-called honeycomb CCD, which is to be used in a digital still camera, having a high fineness and picture quality and more particularly to a suitable solid-state image pick-up device for a digital still camera having a focal plane shutter and the digital still camera.

#### 2. Description of the Related Art

FIG. 11 is a plan view showing a conventional solid-state image pick-up device described in JP-A-10-136391, for example. The solid-state image pick-up device is referred to as a so-called honeycomb pixel arrangement, and photodiodes (photoelectric converting devices) having a large number of green (G) color filters are provided at a predetermined interval vertically and horizontally and photodiodes having blue (B) and red (R) color filters are alternately provided in positions shifted by a  $\frac{1}{2}$  pitch from each photodiode in each row and column.

In the shown example, octagonal frames described as "R", "G" and "B" indicate red, green and blue color filters respectively, and corresponding photodiodes are provided on the lower side thereof (the lower side of the paper).

An electric charge stored in each photodiode is read onto a vertical transfer path 20 formed on the side of each photodiode as shown in an arrow of "a", and is transferred along the vertical transfer path 20 as shown in an arrow of "b" to reach a horizontal transfer path 21, and is then transferred along the horizontal transfer path 21 as shown in an arrow of "c" and is thus read out of the solid-state image pick-up device.

An image processing device provided in the rear stage of the solid-state image pick-up device which is not shown from the amount of the G signal charges read from a G pixel provided around an "R" pixel in addition to the amount of R signal charges read from an "R" pixel position shown in FIG. 11, for example, and similarly estimates the amount of B signal charges in the R pixel position from the amount of the B signal charges read from a B pixel provided around the R pixel. More specifically, the amounts of signal charges having three colors of R, G and B in each pixel position are obtained and a pick-up image can be acquired with a resolution equal to the number of pixels.

As shown in FIG. 12(a), furthermore, the amount of signal charges in a place in which a pixel is not provided is estimated by carrying out an interpolating operation over pixel signals of R, G and B therearound. By using an estimated charge amount on the k point (which will be hereinafter referred to as an imaginary pixel point), it is possible to generate image data on the imaginary pixel point, thereby obtaining an image having a higher resolution than the number of pixels of the solid-state image pick-up device as shown in FIG. 12(b).

As described above, conventionally, a signal charge on an imaginary pixel point k is estimated from surrounding pixel signals so that an image having a high resolution can be obtained. However, the amount of the signal charges on the imaginary pixel point k is persistently estimated from the surrounding pixel signals and the estimation value is different from an actual amount of the signal charges. For this reason, there is a problem in that the effect of enhancing a resolution cannot be obtained in all scenes even if the estimation value is used.

A false signal such as a moiré is generated in a solid-state image pick-up device. Turning back to JP-A-10-136391, it has proposed a solid-state image pick-up device capable of increasing an amount of a light to be received to enhance a light receiving efficiency while increasing the integration of a pixel. The solid-state image pick-up device provides a novel structure capable of optimizing the space sampling of an image. This structure is referred to as a so-called honeycomb pixel array.

In this honeycomb pixel array, if a distance between pixels is set to be a pitch, an arrangement is carried out with a shift of a half pitch in a row direction and/or a column direction, for example. With this pixel arrangement, a transfer register in a vertical direction is formed to meander so as to go around each pixel in a solid-state image pick-up device of a CCD (Charge Coupled Device) type. A color filter segment is assigned to each of pixels (actual pixels) present actually. In the pixel (photoreceptor), a light transmitted from the color filter segment is photoelectrically converted and a signal charge having a color attribute is read onto a vertical transfer register in a vertical direction. In the solid-state image pick-up device, a voltage signal obtained by a Q/V conversion, that is, an analog signal is output through a horizontal transfer register which is orthogonal to a vertical transfer direction.

The analog signal is subjected to a signal processing. In consideration of the color of the actual pixel which is supplied, the correlation of pixel data is acquired. In the signal processing, a color is set, and pixel data in a position in which a pixel is not actually present, that is, pixel data in a virtual pixel and pixel data in a pixel having a different color which is actually present are calculated by using pixel data having the same color and a high correlation. A pixel interpolation processing is carried out by using pixel data in such a direction as to have a high correlation. In the pixel interpolation processing, the generation of a false signal can be suppressed. Moreover, the broadband processing of the pixel data is also carried out to increase a resolving power.

In the signal processing, the correlation of pixel data present around an object pixel is decided to carry out a prediction, thereby generating an object virtual pixel. However, the signal processing does not produce a great advantage for all scenes. If the prediction is erroneously carried out, pixel data to be generated cannot reflect a faithful color and gradation, for example. As a result, there is a possibility that a false signal for an original scene might be generated and a resolution might be deteriorated.

### SUMMARY OF THE INVENTION

It is an object of the invention to provide a solid-state image pick-up device capable of increasing the precision of an estimation value on an imaginary pixel point and obtaining an image having a high resolution and high precision, and a digital still camera using the solid-state image pick-up device.

In order to attain the object, the invention provides a solid-state image pick-up device comprising a photoelectric converting device formed at a predetermined array interval in row and column directions on a semiconductor substrate, a vertical transfer path provided in the column direction of the photoelectric converting device and serving to read and transfer a signal charge obtained by the photoelectric converting device, and a shielding film for covering an upper part of the vertical transfer path, wherein a pore is provided in a place corresponding to an imaginary pixel point position in the shielding film.

By such a structure, it is possible to actually obtain imaginary pixel point data (an imaginary pixel point charge) corresponding to the amount of a received light on an imaginary pixel point. By using the imaginary pixel point data, it is possible to correct image data based on a signal charge.

In the foregoing, it is preferable that the photoelectric converting device should be arranged in the row direction with a shift of a  $\frac{1}{2}$  pitch alternately. By such a structure, the resolution of an image picked up by the solid-state image pick-up device which is referred to as a honeycomb pixel arrangement can be set to be high.

A digital still camera to attain the object comprises the solid-state image pick-up device described above, a focal plane shutter provided in a front part of the solid-state image pick-up device, and an image processing device for reading an imaginary pixel point charge stored in an imaginary pixel point position on the vertical transfer path from the solid-state image pick-up device after the focal plane shutter is closed and then reading a signal charge of the photoelectric converting device from the solid-state image pick-up device, thereby generating image pick-up data from the signal charge and the imaginary pixel point charge. By such a structure, it is possible to obtain a digital still camera capable of picking up an image having a high resolution and rarely having a false signal.

It is another object in this invention to provide a solid-state image pick-up device capable of increasing the precision of an estimation value on an imaginary pixel point and obtaining an image having a high resolution and precision, and a digital still camera using the solid-state image pick-up device.

In order to attain the object, the invention provides a solid-state image pick-up device comprising a photoelectric converting device formed at a predetermined array interval in row and column directions on a semiconductor substrate, a vertical transfer path provided in the column direction of the photoelectric converting device and serving to read and transfer a signal charge by the photoelectric converting device, and a shielding film for covering an upper part of the vertical transfer path, wherein a pore is provided in a place corresponding to an imaginary pixel point position in the shielding film and a storage section for storing an electric charge transferred along the vertical transfer path by a predetermined number of lines and for transferring the electric charge to a horizontal transfer path is provided in a connecting portion of the vertical transfer path and the horizontal transfer path.

By such a structure, it is possible to obtain a static image having a high fineness and picture quality by using information obtained from the photoelectric converting device (main pixel) and information of the imaginary pixel point obtained by a light transmitted through the pore. Moreover, when a dynamic image constituted by only a signal charge of a valid line in each main pixel is to be read out, only the signal charge of the valid line constituting a dynamic image which is transferred along the vertical transfer path is fetched into the storage section so that the transfer speed of the vertical transfer path can be increased. Consequently, it is possible to reduce a smear to be mixed into the dynamic image.

In the foregoing, it is preferable that the photoelectric converting device should be arranged in the row direction with a shift of a  $\frac{1}{2}$  pitch alternately. By such a structure, it is possible to obtain a static image having a higher resolution and picture quality by the solid-state image pick-up device

of a honeycomb pixel arrangement capable of acquiring an image having a high resolution.

A digital still camera to attain the object comprises the solid-state image pick-up device described above, a mechanical shutter provided in a front part of the solid-state image pick-up device, and control means for driving the vertical transfer path at a higher speed than a transfer speed of a static image and fetching, to the storage section, only a signal charge of a valid line constituting a dynamic image when photographing the dynamic image with the mechanical shutter opened. By such a structure, it is possible to reduce the influence of a smear through a pore also when a dynamic image is photographed by a solid-state image pick-up device provided with the pore.

It is a further object in this invention to provide a solid-state image pick-up device and a solid-state image pick-up device which can sample a signal charge supplied from a pixel with higher precision in a position, thereby predicting the generation of a pixel with high precision.

In order to solve the problems, the invention provides a solid-state image pick-up device comprising a photoreceptor provided in a two-dimensional array and serving to convert an incident light into a signal charge, a plurality of vertical transfer means for transferring the signal charge converted by the photoreceptor in a vertical direction, and horizontal transfer means for transferring the signal charge transferred in a horizontal direction which is orthogonal to the vertical transfer means, an interval between devices provided in the vertical and horizontal directions for each of the photoreceptors being set to be a pitch, and the photoreceptors which are adjacent to each other being provided with a shift of an almost half pitch, and the vertical transfer means being formed to make a pair of two lines between the photoreceptors provided in the horizontal direction and being caused to make a detour every line for the photoreceptors which are adjacent to each other, the device comprising a solid-state image pick-up device in which a photoreceptor provided actually is set to be an actual pixel and a photoreceptor assumed to be provided in a space region surrounded by the actual pixel is set to be a virtual pixel, and vertical transfer means which is shielded and vertical transfer means having an optical opening formed in the vicinity of the virtual pixel are provided regularly, shielding means for regulating an exposure time of the solid-state image pick-up device, and signal processing means for carrying out an interpolation processing by the actual pixel using a signal obtained from the opening of the solid-state image pick-up device as data of the virtual pixel.

In the solid-state image pick-up device according to the invention, the shielding means is opened to receive the incident light by means of each of the photoreceptor and the optical opening for a predetermined time and to photoelectrically convert the same incident light, the incident light is shielded by the shielding means to end the exposure, the signal charge generated in each opening is then read as information corresponding to the position of the virtual pixel to maintain precision to be higher than that of the virtual pixel generated by the interpolation processing, the signal charge of the vertical transfer means is thereafter swept away and the signal charge stored in each of the photoreceptors is read onto the vertical transfer means in accordance with a normal processing procedure, and the virtual pixel is used in the interpolation processing for the real pixel by the signal processing means. Consequently, it is possible to enhance the precision for each pixel which is obtained by the interpolation.

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In order to solve the problems, moreover, the invention provides a solid-state image pick-up device comprising a photoreceptor provided in a two-dimensional array and serving to convert an incident light into a signal charge, a plurality of vertical transfer means for transferring the signal charge converted by the photoreceptor in a vertical direction, and horizontal transfer means for transferring the signal charge transferred in a horizontal direction which is orthogonal to the vertical transfer means, an interval between devices provided in the vertical and horizontal directions for each of the photoreceptors being set to be a pitch, and the photoreceptors which are adjacent to each other being provided with a shift of an almost half pitch, and the vertical transfer means being formed to make a pair of two lines between the photoreceptors provided in the horizontal direction and being caused to make a detour every line for the photoreceptors which are adjacent to each other, wherein a photoreceptor provided actually is set to be an actual pixel and a photoreceptor assumed to be provided in a space region surrounded by the actual pixel is set to be a virtual pixel, and first vertical transfer means which is shielded as the vertical transfer means and second vertical transfer means having an optical opening formed in the vicinity of the virtual pixel are provided regularly, and the first vertical transfer means is provided in such a manner that an adjacent photoreceptor to the first vertical transfer means maintains the same relationship with a color array pattern of a color filter segment to be color separated which covers an adjacent photoreceptor to the vertical transfer means by aiming at the same color array pattern.

In the solid-stage image pick-up device according to the invention, the signal charge generated in each opening of the second vertical transfer means is read as a signal charge corresponding to the position of the virtual pixel, the signal charge of the vertical transfer means is then swept away, the signal charge stored in each of the photoreceptors is read onto the vertical transfer means in accordance with a normal processing procedure and is thus transferred to read a signal in static image photographing, and the actual data obtained from the signal charge supplied from the opening positioned in the vicinity of the virtual pixel as well as the signal charge supplied from the photoreceptor provide information with higher precision than that of the estimation data of the virtual pixel generated by the interpolation, while vertical thinning is carried out to read and transfer the signal charge, thereby reading a signal in dynamic image photographing. In the signal reading to be carried out in the dynamic image photographing, normal data maintaining the color array pattern can be obtained for horizontally thinned dynamic image photographing by using only data corresponding to any of the read signal charges which is obtained from the first vertical transfer means.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial plan view showing a solid-state image pick-up device according to the first embodiment of the invention,

FIG. 2 is a sectional view taken along a line II-II in FIG. 1,

FIG. 3 is a flowchart showing an operation procedure for a digital still camera according to the first embodiment,

FIG. 4 is a timing chart corresponding to the flowchart shown in FIG. 3,

FIG. 5 is a partial plan view showing a solid-state image pick-up device according to second embodiment of the invention,

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FIG. 6 is a sectional view taken along a line II-II in FIG. 1,

FIG. 7 is an exploded view showing the solid-state image pick-up device illustrated in FIG. 1,

FIG. 8 is a diagram showing the relationship among a vertical transfer path, a storage section and a horizontal transfer path in the solid-state image pick-up device illustrated in FIG. 5,

FIG. 9 is an operation timing chart showing the solid-state image pick-up device according to the second embodiment of the invention,

FIG. 10 is a partial plan view showing a solid-state image pick-up device according to the third embodiment of the invention,

FIG. 11 is a plan view showing a solid-state image pick-up device in which a honeycomb pixel is arranged according to the related art, and

FIGS. 12(a) and 12(b) show the explanatory views of a data interpolation on an imaginary pixel point.

FIG. 13 is an explanatory view showing the positional relationship among a photoreceptor, a vertical transfer register and an incidence hole in a solid-state image pick-up device to be used in an image pick-up section in a digital camera according to the fourth embodiment,

FIG. 14 is a block diagram showing the schematic structure of the digital camera to which the solid-state image pick-up device according to the fourth embodiment,

FIG. 15 is a front view showing the enlarged main part of the solid-state image pick-up device in FIG. 1 and a sectional view showing the solid-state image pick-up device taken along a cutting line III-III,

FIG. 16 is a main flowchart for explaining a photographing procedure in the digital camera of FIG. 2,

FIG. 17 is a flowchart for explaining an operation procedure in a static image photographing mode shown in FIG. 16,

FIG. 18 is a flowchart for explaining the rest of the operation procedure in FIG. 17,

FIGS. 19(a) to 19(d) show the diagrams showing the comparison of images obtained by photographing an object in the procedures of FIGS. 5 and 6 and the past procedures,

FIG. 20 is a flowchart for explaining an operation procedure in a dynamic image photographing mode shown in FIG. 16,

FIG. 21 is an explanatory view showing such a relationship that the formation position of the incidence hole is varied in the solid-state image pick-up device in FIG. 13,

FIG. 22 is an explanatory view showing the relationship of the formation position of the incidence hole in which  $\frac{1}{2}$  thinning is carried out in the solid-state image pick-up device in FIG. 13, and

FIG. 23 is an explanatory view showing the relationship of the formation position of the incidence hole in which  $\frac{1}{4}$  thinning is carried out in the solid-state image pick-up device in FIG. 13.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first embodiment in this invention will be described below with reference to the drawings.

FIG. 1 is a partial plan view showing a solid-state image pick-up device (a CCD in this example) mounted on a digital still camera according to the embodiment of the invention, and FIG. 2 is a sectional view taken along a line II-II in FIG. 1. A p well 2 is formed on an n-type semiconductor substrate 1 of the solid-state image pick-up device according to the



embodiment, and pixels (photodiodes PD) **3r**, **3g** and **3b** of a honeycomb arrangement are formed on the p well **2**. A color filter corresponding to each pixel color is provided on each of the photodiodes PD (photoelectric converting devices), which is not shown in FIG. 2.

Vertical transfer paths **4a**, **4b**, **4c**, . . . extended zigzag in a column direction are formed between the pixels **3r**, **3g** and **3b**, and two transfer electrodes constituting the vertical transfer paths are formed on both sides of each pixel (indicated as ①, ②, ③ and ④ in FIG. 1). When a predetermined voltage is applied to the transfer electrode, a potential well is formed on the p well **2** in the lower position of the transfer electrode as shown in FIG. 2.

In the example shown in FIG. 1, the signal charge of a pixel **3b** is read onto the vertical transfer path **4b** and the signal charge of a pixel **3g** is read onto the vertical transfer path **4c**, and they are transferred. The signal charge to be transferred is read from the pixel **3b** onto a potential well formed in the lower part of the transfer electrode ① the reading is carried out by applying a reading voltage to a reading electrode which is not shown), for example.

Next, a predetermined voltage is applied to the transfer electrode ② to form a potential well and the application of the predetermined voltage to the transfer electrode ① is stopped to eliminate the potential well. Consequently, the signal charge is moved from the lower position of the transfer electrode ① to the lower position of the transfer electrode ②. Subsequently, the signal charge proceeds to the transfer electrode ③ and is then transferred to a horizontal transfer path shown in FIG. 7 or 8 in the same manner. More specifically, the predetermined voltage is applied to the transfer electrodes ①, ②, ③ and ④ in order so that the signal charge is transferred in a vertical direction in the example shown in FIG. 1.

In the examples shown in FIGS. 1 and 2, the adjacent vertical transfer paths **4b** and **4c** are separated from each other through a channel stop **5**. Consequently, the potential well provided between the vertical transfer paths **4b** and **4c** is separated. The other adjacent vertical transfer paths are also separated in the same manner.

In the case in which a signal charge is to be transferred along the vertical transfer paths **4a**, **4b**, . . . , a noise is mixed into the signal charge to deteriorate picture quality when a light is incident on the potential well. For this reason, a shielding film **6** is provided on the transfer electrodes **4a**, **4b**, . . . as shown in FIG. 2 in such a manner that the light is not incident on the potential well during the transfer of the signal charge.

In the embodiment, a pore (hole) **7** is opened in a position to be an almost middle position of four pixels provided therearound in the shielding film **6** and the transfer electrode ① provided thereunder, that is, a position of an imaginary pixel point in which a photodiode is not present but image data are created by using the signal charge of surrounding pixels (photodiodes) in such a manner that the light is incident on the potential well of the transfer electrode ①.

When a noise made by the light incidence is mixed into the signal charge which is being transferred, the picture quality is deteriorated as described above. However, it is premised that the solid-state image pick-up device according to the embodiment is provided in a digital still camera mounting a focal plane shutter thereon. Since a shutter is closed during the transfer of the signal charge, an external light does not enter the potential well.

FIG. 3 is a flowchart showing an image pick-up procedure in the digital still camera comprising the solid-state image pick-up device and FIG. 4 is a timing chart thereof. An

ordinary digital still camera usually starts photographing by means of an electronic shutter and ends the photographing by means of a mechanical shutter. The digital still camera according to the embodiment mounts the focal plane shutter as described above and is characterized in that a process from the start of photographing to the end of the photographing is carried out by mechanical control through the focal plane shutter.

When a power supply is turned ON to pick up an image by means of the digital still camera (a step S1) and a photographer touches a two-stage type shutter release button by fingers, an SW1 switch is first turned ON (a step S2). Consequently, the driving operation of the solid-state image pick-up device is started and a high-speed sweeping pulse is applied to each of the transfer electrodes ①, ②, ③ and ④ of the vertical transfer path in order so that a noise charge remaining in the vertical transfer path is swept away (a step S3). Simultaneously with the sweeping processing, an automatic exposure processing and an autofocus processing are carried out according to an external sensor at a step S4.

Subsequently, when the photographer completely presses the shutter release button, an SW2 switch is turned ON (a step S5). Consequently, the sweeping processing of the vertical transfer path is ended and a predetermined voltage is applied to the transfer electrode ① having the pore **7** formed thereon and a potential well is formed under the transfer electrode ① (a step S6).

Next, the first film of the focal plane shutter runs to start an exposure (a step S7) and it is decided whether a preset exposure time is over or not (a step S8). When it is decided that the exposure is completed, the second film of the focal plane shutter runs to actually end the exposure (a step S9).

By the exposure, the signal charge of a static image corresponding to the exposure time is stored in the photodiode PD, and at the same time, an electric charge corresponding to the exposure time is stored in the potential well of the transfer electrode ①. The electric charge entering the potential well of the transfer electrode ① is equivalent to a signal charge on an imaginary pixel point surrounded by four pixels. The electric charge is read from the solid-state image pick-up device and can be thereby utilized as a signal charge on the imaginary pixel point (which will be hereinafter referred to as imaginary pixel point data).

In the embodiment, the imaginary pixel point data are previously transferred along a vertical transfer path and are then transferred along a horizontal transfer path to read the electric charge from the solid-state image pick-up device (a step S10) and to store the same electric charge in a memory.

Next, a reading pulse is applied to a reading electrode which is not shown, the signal charge (image data) of the pixel (photodiode PD) is read onto the vertical transfer path, and is transferred to the vertical transfer path and the horizontal transfer path and is then read from the solid-state image pick-up device (a step S11) and is stored in the memory.

At a next step S12, an image processing is carried out by using the image data stored in the memory and the imaginary pixel point data, and the image data generated as a processing result are recorded in the memory (a step S13) to end the processing.

As a method of using the imaginary pixel point data, for example, a signal charge on the imaginary pixel point is estimated by using the signal charge of a photoelectric converting device and a value obtained by the estimation is corrected by using the imaginary pixel point data in the same manner as in the conventional art. Alternatively, since the imaginary pixel point data are signal charges which are not

transmitted through a color filter, they are set to be luminance data and the image data read from the pixel are corrected by the luminance data. Thus, various methods can be proposed for the method of using the imaginary pixel point data.

In the embodiment, thus, it is possible to obtain actual information on the imaginary pixel point with such a simple structure that a hole is opened in the position of the imaginary pixel point. Consequently, it is possible to reduce a false signal by using the imaginary pixel point data or increasing the resolution of an image.

In the embodiment, the pore 7 is provided in a position which is slightly shifted from the middle position of four pixels as shown in FIG. 1. The reason is that the transfer of the imaginary pixel point data is to be carried out easily. However, it is also possible to provide the position of the pore 7 in the true middle position of four surrounding pixels.

FIG. 5 is a plan view showing an example in which a pore 8 is provided in the center of the four surrounding pixels 3r, 3g and 3b. The transfer electrode of each of the vertical transfer paths 4a, 4b and 4c is represented by ①, ②, ③, ④ and ⑤ as shown in FIG. 5. In the case in which the imaginary pixel point data are to be stored in the potential well through the pore 8, a predetermined voltage is applied to the transfer electrodes ①, ③ and ⑤ to form the potential well and to prevent the potential well from being formed on the transfer electrodes ② and ④.

Consequently, the imaginary pixel point data stored through the pore 8 are stored in the transfer electrodes ①, ③ and ⑤. In this case, the imaginary pixel point data are separately stored in two adjacent potential wells partitioned by the channel stop 5. After the transfer, therefore, a value obtained by adding two adjacent imaginary pixel point data becomes true imaginary pixel point data.

In this case, moreover, the potential well is formed every other transfer electrode in a vertical transfer direction. Therefore, the imaginary pixel point data are transferred through a so-called accordion transfer in order from the vertical transfer electrode on the horizontal transfer path side.

Next, the second embodiment in this invention will be described below with reference to the drawings.

FIG. 5 is a partial plan view showing a solid-state image pick-up device (a CCD in this example) mounted on a digital still camera according to the embodiment of the invention, and FIG. 6 is a sectional view taken along a line II-II in FIG. 5. A p well 2 is formed on an n-type semiconductor substrate 1 of the solid-state image pick-up device according to the embodiment, and pixels (photodiodes PD) 3r, 3g and 3b of a honeycomb arrangement are formed on the p well 2. As shown in FIG. 6, moreover, a color filter 110 corresponding to each pixel color and a microlens 11 are provided in the upper part of each photodiode PD (photoelectric converting device). FIG. 7 is an exploded view thereof.

Vertical transfer paths 4a, 4b, 4c, . . . extended zigzag in a column direction are formed between the pixels 3r, 3g and 3b, and two transfer electrodes constituting the vertical transfer paths are formed on both sides of each pixel (indicated as ①, ②, ③, ④ and ⑤ in FIG. 5). When a predetermined voltage is applied to the transfer electrode, a potential well is formed on the p well 2 in the lower position of the transfer electrode as shown in FIG. 6.

In the example shown in FIG. 5, the signal charge of a pixel 3b is read onto the vertical transfer path 4b and the signal charge of a pixel 3g is read onto the vertical transfer path 4c, and they are transferred. The signal charge to be transferred is read from the pixel 3b onto a potential well

formed in the lower part of the transfer electrode ③ (the reading is carried out by applying a reading voltage to a reading electrode which is not shown), for example.

Next, a predetermined voltage is applied to the transfer electrode ④ to form a potential well and the application of the predetermined voltage to the transfer electrode ③ is stopped to eliminate the potential well. Consequently, the signal charge is moved from the lower position of the transfer electrode ③ to the lower position of the transfer electrode ④. Subsequently, the signal charge proceeds to the transfer electrode ⑤ and is then transferred to a horizontal transfer path in the same manner. More specifically, the predetermined voltage is applied to the transfer electrodes ①, ②, ③, ④ and ⑤ in order so that the signal charge is transferred in a vertical direction in the example shown in FIG. 5.

In the examples shown in FIGS. 5 and 6, the adjacent vertical transfer paths 4b and 4c are separated from each other through a channel stop 5. Consequently, the potential well provided between the vertical transfer paths 4b and 4c is separated. The other adjacent vertical transfer paths are also separated in the same manner.

In the case in which a signal charge is to be transferred along the vertical transfer path, a noise charge is mixed into the signal charge to deteriorate picture quality when a light is incident on the potential well. For this reason, a shielding film 6 is provided on the transfer electrodes 4a, 4b, as shown in FIG. 6 in such a manner that the light is not incident on the potential well during the transfer of the signal charge.

In the embodiment, however, a pore (hole) 8 is opened in a position to be a middle position of four pixels provided therearound in the color filter 110, the shielding film 6 and the transfer electrode provided thereunder, that is, a position of an imaginary pixel point k in which a photodiode is not present but image data are created by using the signal charge of surrounding pixels (photodiodes PD) in such a manner that the light is incident on the potential well of the transfer electrode 4.

When a noise charge made by the light incidence is mixed into the signal charge which is being transferred, the picture quality is deteriorated in the embodiment, however, the transfer is carried out with the mechanical shutter closed when the signal charge for a static image is read out of the photodiode and is thus transferred as will be described below. Consequently, the noise is not mixed into the signal charge.

The signal charge for a dynamic image is to be transferred with the mechanical shutter opened. For this reason, a noise charge is inevitably mixed by a light incidence. In the embodiment, however, the transfer speed of the vertical transfer path is increased as will be described below in order to lessen the noise charge, and furthermore, a storage section 13 is provided between the vertical transfer paths 4a, 4b, . . . and a horizontal transfer path 112 as shown in FIG. 8. The storage section 13 can store data for four lines in the shown example.

The storage section 13 has such a structure as to store the signal charges of a line which is transferred from the vertical transfer paths 4a, 4b, . . . and to sequentially shift the signal charges to the horizontal transfer path 112. In the case in which a static image is picked up, the signal charges of all pixels are read onto the vertical transfer paths and are sequentially transferred to the horizontal transfer path 112 through the storage section 13.

On the other hand, a dynamic image does not need an image having a high fineness differently from the static image. For this reason, a one-frame image for the dynamic

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image is constituted by only the thinned pixel data. For example, a signal charge for a pixel in a first row, a signal charge for a pixel in a fourth row, . . . are read out to constitute each frame image of the dynamic image. In this case, the signals of valid lines corresponding to a second row, a third row, . . . a fifth row, a sixth row, . . . are also transferred along the vertical transfer paths **4a**, **4b**, . . . . Therefore, the signals of the invalid lines are discarded toward the back side of the substrate of the solid-state image pick-up device immediately before entering the storage section **13** and only the signal of the valid line is fetched into the storage section **13** and is shifted up to the horizontal transfer path **112**.

By increasing the transfer speed of the vertical transfer path, thus, it is possible to shorten a time required for an exposure to a light through the pore **8**. Consequently, it is possible to reduce a noise charge entering the vertical transfer path through the pore **8**. For example, if the number of lines to be read as a dynamic image for all lines of the main pixel of the solid-state image pick-up device is set to be  $\frac{1}{4}$  and the number of lines to be provided in the storage section **13** is set to be four, the transfer speed of the vertical transfer path can be increased to be four times as high as an ordinary transfer speed for reading a static image. Consequently, a smear can be reduced to be  $\frac{1}{4}$ .

FIG. **9** is a chart showing an image pick-up timing in the digital still camera comprising the solid-state image pick-up device. In accordance with the timing chart, description will be given to the fetch of a static image and that of a dynamic image. First of all, the fetch of a static image will be described.

A static image is fetched by reading a signal charge stored in each pixel (photodiode) during an exposure time from the "open" of an electronic shutter to the "close" of a mechanical shutter. In the solid-state image pick-up device according to the embodiment, however, an electric charge stored in the imaginary pixel point is also utilized. Therefore, a signal remaining in the storage section **13** is first shifted by the number of lines with a pulse "a" shown in FIG. **9** and is discarded by closing the mechanical shutter.

Next, a transfer is carried out with a transfer pulse having a predetermined cycle by synchronizing the vertical transfer paths **4a**, **4b**, . . . with the storage section **13**, and the electric charge stored in the imaginary pixel point is transferred up to the horizontal transfer path **112**, and is then transferred along the horizontal transfer path **112** and is thus read out of the solid-state image pick-up device.

When an electric charge is to be stored in the imaginary pixel point so as to be stored well under the corresponding transfer electrode, the driving pulse of each transfer electrode is brought into a stop state with a potential well formed under the corresponding transfer electrode (the transfer electrodes **2** and **4** in FIG. **5**, for example). In this case, the sum of the electric charges stored in the left and right transfer electrodes **2** divided by the channel stop **5** represents the electric charges stored in the imaginary pixel point.

When the electric charge in the imaginary pixel point is completely read out, a reading pulse "b" is then applied to a reading gate and the signal charge of the photodiode is read onto the vertical transfer path. Thereafter, the signal charge is transferred by a transfer pulse having a predetermined cycle and is read out of the solid-state image pick-up device.

As a method of using the imaginary pixel point data, for example, a signal charge on the imaginary pixel point is estimated by using the signal charge of a photoelectric converting device and a value obtained by the estimation is corrected by using the imaginary pixel point data in the same

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manner as in the conventional art. Alternatively, since the imaginary pixel point data are signal charges which are not transmitted through a color filter, they are set to be luminance data and the image data read from the pixel are corrected by the luminance data. Thus, various methods can be proposed for the method of using the imaginary pixel point data.

When the size of the pore **8** is set to be smaller than the area of the main pixel (photodiode PD), an image obtained from the main pixel has a high sensitivity and an image obtained through the pore **8** (imaginary pixel) has a low sensitivity. Therefore, it is possible to generate an image having a wide dynamic range from these two images. In other words, it is possible to increase the dynamic range of the digital still camera.

In the embodiment, thus, actual information on the imaginary pixel point can be obtained with such a simple structure that a hole is opened in the position of the imaginary pixel point. Consequently, a false signal can be reduced by using the imaginary pixel point data or the resolution of an image can be increased.

Next, the fetch of a dynamic image will be described. In the case in which a dynamic image is to be picked up, the mechanical shutter is "open" and an exposure time is determined by only the electronic shutter, and a signal charge is stored in each pixel. The signal charge of a pixel constituting the dynamic image is read onto the vertical transfer path with a reading pulse "c" which is synchronous with a vertical synchronization signal VD. Prior to each pulse "c", noises remaining on the vertical transfer path **4** and the storage section **13** are first swept away with a sweeping pulse "d" and the signal charge of the main pixel of the valid line constituting the dynamic image is then read onto the vertical transfer path **4** with the reading pulse "c".

Next, the signal charge read onto the vertical transfer path **4** is transferred to the storage section **13** at a high speed with a high-speed transfer pulse "e" and only the signal charge of the valid line constituting the dynamic image is fetched into the storage section **13**. Then, the storage section **13** shifts the signal charge to the horizontal transfer path **112** with a transfer pulse "f" having a predetermined cycle and the signal charge transferred along the horizontal transfer path **112** is read out of the solid-state image pick-up device.

The transfer pulse "e" for transferring the signal charge read onto the vertical transfer path to the storage section **13** is a high-speed pulse. Therefore, the signal charge is delivered to the storage section **13** in a short time. If the time is short, the amount of noise charges passing through the pore **8** during a transfer in the vertical transfer path is lessened so that the picture quality of the dynamic image is not deteriorated. Consequently, a smear entering the dynamic image is lessened, and furthermore, a deterioration in the picture quality of an image displayed in a display section on the back of the digital still camera for displaying a dynamic image is also reduced.

In the embodiment, there has been described the example in which the pore **8** is provided in the center of the four surrounding pixels **3r**, **3g** and **3b**. However, the pore **8** does not need to be always provided in the center of the four surrounding pixels **3r**, **3g** and **3b** and can also be provided in a shifted position in order to simply carry out the transfer. In FIG. **6**, the pore **7** is provided in a slightly shifted position to enter one transfer electrode. Thus, the electric charge on the imaginary pixel point can be stored in one of the four transfer electrodes in the transfer direction of the vertical transfer path and the transfer pulse of the imaginary pixel point data can easily be created.

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Next, the fourth embodiment of a solid-state image pick-up device according to the invention will be described in detail with reference to the accompanying drawings.

In the embodiment, the solid-state image pick-up device according to the invention is applied to a digital camera **10**. The illustration and description of portions which are not directly related to the invention will be omitted. In the following description, a signal is indicated as the reference numeral of a connecting line on which it appears.

The digital camera **10** is characterized by the solid-state image pick-up device of an image pick-up section **12** as shown in FIG. **13**. The image pick-up section **12** of FIG. **13** represents the array of a photoreceptor **120** for carrying out a photoelectric conversion seen from the incidence side of an incident light. A horizontal transfer register in the image pick-up section **12** is formed in the same manner as that in the conventional art and illustration is therefore omitted.

If a spacing between the photoreceptors (pixels) in a horizontal or vertical direction is set to be a pixel pitch, one of the photoreceptors **120** which is adjacent to the other photoreceptor **120** is provided in a position indicative of an almost half of a pixel pitch in each direction. Moreover, vertical transfer registers **122** and **122** for two lines are formed between the pitch of the photoreceptors **120**, respectively. Such an array of the photoreceptors is a so-called honeycomb array. In the case in which the photoreceptor **120** is set to be an actual pixel which is actually present, a region having no photoreceptor surrounded by four photoreceptors **120** is set to be a virtual pixel region in the image pick-up section **12**.

In the image pick-up section **12** to be one of the features according to the invention, an incidence hole **124** is interposed between four existing photoreceptors **120** and is thus formed on a left one of the vertical transfer registers **122** and **122** in the two lines. If the incidence hole **124** is formed in coincidence with a virtual pixel, a signal charge cannot be held. For this reason, the incidence hole **124** is formed in the vicinity of the virtual pixel. Moreover, the incidence hole **124** is not formed on the vertical transfer register **122** in one line but the vertical transfer registers **122** and **122** in two lines in consideration of the array pattern of a color filter segment. Characters R, G and B described in the photoreceptor **120** indicate the color of the color filter segment. The array pattern of the color filter segment to be used is a G square RB perfect checker pattern. The incidence hole **124** is formed with such a relationship that three lines are set to be a device. Further description will be given later.

The digital camera **10** comprises an optical lens system **14**, a diaphragm regulating mechanism **16**, a mechanical shutter **18**, a preprocessing section **20**, a signal processing section **22**, an operating section **24**, a system control section **26**, a timing signal generating section **28**, a driver **30**, a monitor **32** and a storage **34** in addition to the image pick-up section **12** (see FIG. **14**). The optical lens system **14** includes a zoom mechanism for regulating the angle of view of a field and an automatic focus (AF) regulating mechanism for automatically displacing and regulating the arrangement of a plurality of optical lenses and adjusting an object to have a focused positional relationship, which are not shown. Each of the mechanisms is provided with a motor for moving the optical lens in the position described above. These mechanisms are operated in response to a driving signal **30a** supplied from the driver **30** to each of the motors.

The diaphragm regulating mechanism **16** is an AE (Automatic Exposure) regulating mechanism for regulating an amount of an incident light which is not specifically shown, and serves to rotate a ring section in response to a driving

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signal **30b** sent from the driver **30**. The ring section causes blades to partially overlap and causes an iris to have a round shape, and forms the iris in such a manner that an incident luminous flux is transmitted therethrough. Thus, the diaphragm regulating mechanism **16** changes the aperture of the iris. The diaphragm regulating mechanism **16** may be incorporated in the optical lens system **14** by setting the mechanical shutter **18** to be a lens shutter.

The mechanical shutter **18** has the function of shielding a light to be irradiated on the image pick-up section **12** only during photographing and determining an exposure time by the start and end of exposure. The mechanical shutter **18** has such a focal plane type as to be used in a single-lens reflex camera, for example. In this type, exposure is carried out by a slit formed the moment a shutter screen runs longitudinally or transversely. Moreover, the lens shutter type may be used as described above. The mechanical shutter **18** is opened or closed in response to a driving signal **30c** supplied from the driver **30**.

The image pick-up section **12** includes an optical low-pass filter **12a**, a color filter **12b** and a solid-state image pick-up device **12c**. The optical low-pass filter **12a** serves to set the spatial frequency of an incident light to be equal to or lower than a Nyquist frequency. The color filter **12b** has a color filter segment for primaries RGB provided with a predetermined positional relationship one-on-one to each of photoreceptors (photosensitive cells) of the solid-state image pick-up device **12c**. Accordingly, the color filter depends on the arrangement of the photoreceptor of the solid-state image pick-up device **12c**.

The solid-state image pick-up device **12c** includes a charge coupled device (CCD) and a metal oxide semiconductor (MOS). A driving signal **30d** is also supplied from the driver **30** to the solid-state image pick-up device **12c**. The driving signal **30d** is supplied to the solid-state image pick-up device **12c** according to an operation mode. In a static image photographing mode in the operation modes, the solid-state image pick-up device **12c** reads a signal charge stored in the vertical transfer register **122** and is stored in a buffer memory, and then reads a signal charge generated by a photoelectric conversion from the photoreceptor **120** at time of an exposure onto the vertical transfer register through a gate, and shifts and horizontally transfers the signal charge transferred to a horizontal transfer register provided in an orthogonal direction to the register, that is, a horizontal direction.

In a dynamic image photographing mode, moreover, the solid-state image pick-up device **12c** reads a signal charge generated by photoelectrically converting the exact signal charge of the vertical transfer register from the photoreceptor **120** at time of the exposure onto the vertical transfer register through the gate, and shifts and horizontally transfers the signal charge transferred to the horizontal transfer register provided in an orthogonal direction to the register, that is, a horizontal direction. In the vertical transfer, the solid-state image pick-up device **12c** mixes the signal charges sent from pixels having the same color or carries out thinning reading in the vertical direction in consideration of a color array, thereby increasing the speed of signal reading. For example, in the case in which two horizontal transfer registers are provided, a line shift is carried out to mix the signal charges having the same color for a horizontal blanking period. In the G square RB perfect checker pattern,  $\frac{1}{4}$  thinning is carried out for the vertical thinning to read the signal charge, for example.

The signal charge transferred horizontally is Q/V converted into a voltage signal by using a floating diffusion

amplifier (FDA) for an output amplifier in any mode. The image pick-up section 12 outputs an analog signal 12d thus obtained by the Q/V conversion to the preprocessing section 20.

The preprocessing section 20 includes a correlated double sampling (CDS) circuit for noise removal, a gain control amplifier (GCA) and an A/D converter (an Analog-to-Digital converter). The preprocessing section 20 outputs, as digital data 20a, all image pick-up data obtained by carrying out noise removal, waveform shaping and digitization over the supplied analog signal 12d through a system bus 100 to the signal processing section 22.

The signal processing section 22 includes a signal generating circuit, a memory, a gamma correcting circuit, an evaluation value calculating section, a pixel interpolation processing circuit, a color difference matrix processing circuit, and a compression/expansion processing circuit which are not shown. A control signal 26b is supplied from the system control section 26 to the signal processing section 22. The signal generating circuit of the signal processing section 22 which is not shown is operated in response to the control signal 26b. The signal generating circuit has a PLL (Phase Locked Loop) circuit capable of generating a plurality of frequencies. The signal generating circuit multiplies, as a reference clock, an oscillation frequency generated from a source and thus generates plural kinds of clock signals 22a and outputs a clock signal 22b to the system control section 26 and the timing signal generating section 28 through the system bus 100.

On the other hand, a timing signal is supplied from the timing signal generating section 28 to the signal processing section 22, which is not shown. The timing signal includes a horizontal synchronization signal HD, a vertical synchronization signal VD and an operating clock of each section which will be described below.

The image data 20a are input to the memory through the system bus 100 and a data bus 22c for inputting/outputting a signal and are temporarily stored in the memory. Image data in the incidence hole 124, that is, the past virtual pixels are distinguished and treated as existing information in the static image photographing mode and are stored in the memory. Information sent from the incidence hole 124 is variably treated depending on the presence of the color filter segment on the incidence hole 124. When the color filter segment is not present, the acquired information is treated as high-pass luminance data  $Y_H$ . When the color filter segment is present, the acquired information is treated as pixel data having a color attribute.

Moreover, image data obtained from the signal charge which is  $\frac{1}{4}$  thinned in a vertical direction without taking the incidence hole 124 into consideration are supplied to the memory in a dynamic image photographing mode in the same manner as in the normal case. The memory carries out thinning reading in a horizontal direction in order to increase an aspect ratio and a signal reading speed in the reading operation. Also in this case, image data are read so as not to break a color array pattern. The incidence hole 124 is formed in case of FIG. 1 in such a manner that an original color array pattern is maintained in the memory and the image data acquired through the vertical transfer register having no incidence hole 124 are read out even if the thinning in the horizontal direction is carried out. As a result, the image data are  $\frac{1}{3}$  thinned in the horizontal direction and are thus read out.

The memory supplies the stored image data to the gamma

correcting circuit. The gamma correcting circuit includes a look-up table for a gamma correction, for example. The gamma correcting circuit carries out the gamma correction over the image data supplied as one of preprocessings in an image processing by using the data of the table. The gamma correcting circuit supplies the image data subjected to the gamma correction to the evaluation value calculating section and the pixel interpolation processing circuit, respectively.

The evaluation value calculating section includes an arithmetic circuit for calculating a diaphragm stop and shutter speed, a white balance (which will be hereinafter referred to as WB) regulation value and a gradation correction value. The evaluation value calculating section calculates each proper parameter by an arithmetic processing based on the supplied image data in the circuit described above. The results of the calculation are supplied as a parameter 22d to the system control section 26 through the data bus 22c and the system bus 100.

The evaluation value calculating section is not always provided in the signal processing section 22 but may be provided in the system control section 26. In this case, the signal processing section 22 supplies the image data subjected to the gamma correction to the system control section 26.

The pixel interpolation processing circuit has the function of interpolating, generating and calculating pixel data. The image pick-up section 12 uses the color filter 12b formed of a single plate. Therefore, colors other than the real color of the color filter segment cannot be obtained from the image pick-up device. The pixel interpolation processing circuit generates, through an interpolation, pixel data having the color which cannot be obtained in the static image photographing mode. The pixel interpolation processing circuit supplies plain image data to the color difference matrix processing circuit.

The pixel interpolation processing circuit may have the function of increasing the band of the generated pixel data. In the case in which the solid-state image pick-up device 12c of a so-called honeycomb type is used for the image pick-up section 12, moreover, the pixel interpolation processing circuit generates pixel data on primaries RGB by an interpolation processing in a position in which a pixel is actually present (an actual pixel) and a position in which the pixel is not present (a virtual pixel) by using the image data subjected to the gamma correction.

Pixel data in the virtual pixel position corresponding to the incidence hole 124 are exactly used as real existing information. For example, in the case in which the pixel data are high-pass luminance data  $Y_H$ , the pixel interpolation processing circuit uses the high-pass luminance data  $Y_H$  in place of luminance data generated by surrounding estimation. By using the information obtained actually, thus, it is possible to increase the precision of the pixel data in the virtual pixel position as compared with the luminance data obtained by the estimation. Referring to the pixel data having a color attribute, similarly, it is possible to increase precision of a data level as compared with an average level obtained by the estimation. Accordingly, it is possible to accurately express the edge of a generated image and a color boundary. This greatly contributes to an enhancement in a resolution and the effect of suppressing a false color.

The color difference matrix processing circuit generates luminance data Y and color data Cb and Cr by using image data supplied from the pixel interpolation processing circuit and a predetermined coefficient. The image data thus generated are supplied to the compression/expansion processing circuit.

The compression/expansion processing circuit carries out a compression processing over the image data (Y/C) supplied in the static image or dynamic image (movie) mode in standards of JPEG (Join Photographic coding Experts Group), MPEG (Moving Picture coding Experts Group)-1 and MPEG-2, respectively. The compression/expansion processing circuit sends the compressed image data to a storage **34** through the data bus **22c**, the system bus **100** and a data bus **34a** and records the same image data in the storage **34**. The compression/expansion processing section supplies the image data recorded in the storage **34** through the data bus **34a**, the system bus **100** and the data bus **22c** and carries out an expansion processing. The expansion processing is reverse to the compression processing.

Moreover, the signal processing section **22** carries out an RGB conversion over the generated image data or the image data (Y/C) expanded with a reproduction, and supplies the image data **22c** subjected to the RGB conversion to the monitor **32** through the system bus **100** and a data bus **32a**. The image of the image data **22c** supplied by a display controller (not shown) is displayed on the monitor **32** by an operation carried out through a display device.

In the case in which image data are to be input/output to/from an external apparatus, it is preferable that the signal processing section **22** should be provided with an external I/F circuit which is not shown. Examples of the external I/F circuit include a PIO (Programmed Input/Output), a UART (Universal Asynchronous Receiver/Transmitter: a transmitting/receiving circuit for an asynchronous serial communication), a USB (Universal Serial Bus), and an interface based on IEEE1394 standards (the Institute of Electrical and Electronics Engineers).

The PIO is an interface section capable of changing an input/output based on a program. The UART is a device to be used in a serial interface. The device has the function of converting a supplied parallel signal into a serial signal and converting a serial signal sent from a serial device into a parallel signal. The I/F based on the IEEE1394 standards supports a data transfer up to 400 Mbps, for example.

The operating section **24** includes a mode selecting section **24a** and a release shutter button **24b**. The mode selecting section **24a** selects either a static image photographing mode or a dynamic image photographing mode. The mode selecting section **24a** outputs a selected mode signal **24c** to the system control section **26**. The release shutter button **24b** has a stroke in two stages and outputs, to the system control section **26**, a trigger signal **24d** for setting the digital camera **10** into a preliminary image pick-up stage (S1) in a stroke of a first stage and setting the digital camera **10** into a regular image pick-up stage (S2) in a stroke of a second stage. The operating section **24** may further be provided with a zoom selecting switch and a cross button and may have the function of selecting the condition to be displayed on a liquid crystal display panel.

The system control section **26** is a microcomputer or a CPU (Central Processing Unit) which serves to control a general purpose portion of a whole camera and a portion for carrying out a digital processing. The system control section **26** sets the digital camera **10** into the static image photographing mode or the dynamic image photographing mode in response to the supplied mode signal **24c**. The system control section **26** generates a control signal **26a** upon receipt of the setting mode signal **24c** and the trigger signal **24d** for giving a notice of an image pick-up timing from the release shutter button **24b**. The control signal **26a** thus generated is supplied as control signals **26b** and **26c** to the

signal processing section **22** and the timing signal generating section **28** through the system bus **100**, respectively.

The system control section **26** generates the control signal **26a** in consideration of a line interpolation in the signal processing section **22**, a control for the signal generating circuit and a control for the execution of a signal processing. Moreover, the system control section **26** also carries out a read/write control in the preprocessing section **20** and the storage **34**, which is not shown.

The timing signal generating section **28** generates a timing signal in response to the control signal **26c** supplied from the system control section **26** on the basis of the clock signal **22b** supplied from the signal processing section **22**. The timing signal includes a vertical synchronization signal, a horizontal synchronization signal, a field shift pulse, a vertical transfer signal and a horizontal transfer signal. The timing signal generating section **28** supplies these timing signals **28a** thus generated to the driver **30**, the preprocessing section **20**, and the signal processing section **22** and the system control section **26** which are not shown in response to an operation, respectively.

The driver **30** has a driving circuit for generating driving signals **30a**, **30b**, **30c** and **30d** based on the timing signal **28a** and the control signal **26c** which are supplied. The driver **30** supplies the driving signals **30a** and **30b** to the optical lens system **14** and the diaphragm regulating mechanism **16** based on the control signal **26c** to carry out an AF regulation and an AE regulation, respectively. The driver **30** outputs, to the mechanical shutter **18**, the driving signal **30c** for opening or closing the mechanical shutter **18** in response to a regular image pick-up timing supplied from the release shutter button **24b**. Moreover, the driver **30** supplies, to the solid-state image pick-up device **12c**, the driving signal **30d** generated based on the timing signal **28a**, stores a signal charge in each photoreceptor **120** for an exposure period and transfers the stored signal charge through a vertical transfer register and a horizontal transfer register.

The image data **22c** are supplied from the signal processing section **22** to the monitor **32** through the system bus **100** and the data bus **32a**. In general, a liquid crystal monitor is used for the monitor **32**. The liquid crystal monitor is provided with a liquid crystal display controller. The liquid crystal display controller carries out a switching control by the arrangement of liquid crystal molecules and the application of a voltage based on the image data **22c**. By the control, the liquid crystal monitor displays an image. It is apparent that the monitor **32** is not restricted to the liquid crystal monitor but a display apparatus having a small size and capable of confirming an image and suppressing power consumption can sufficiently be used.

The storage **34** records the image data supplied from the signal processing section **22** through the data bus **22c**, the system bus **100** and the data bus **34a** by using a recording medium such as a semiconductor memory. An optical disk or a magneto-optical disk may be used for the recording medium. The storage **34** writes/reads data by using a recording and reproducing head through suitable pick-up for each recording medium or a combination of the pick-up and a magnetic head. The data are written/read corresponding to the control of the system control section **26**, which is not shown.

The solid-state image pick-up device **12c** will be described again. The main part of the solid-state image pick-up device **12c** is enlarged and the incidence hole **124** is formed on one of the sides of the vertical transfer register **122** as shown in FIG. **15**. The incidence hole **124** is formed in the vertical transfer register **122** in the vicinity of an

original virtual pixel as described above. There is illustrated a section obtained by taking away the solid-state image pick-up device **12c** along a cutting line III-III. A p well **42** is formed on an n-type silicon wafer **40**. The p well **42** is formed to divide the regions of the photoreceptor **120** and the vertical transfer register **122**. An n layer (not shown) is formed as a photodiode in the region of the photoreceptor **120** thus divided and a p<sup>+</sup> layer is formed thereon.

A p well is formed in a region of the vertical transfer register **122** which is not shown and an n layer is formed thereon. A gate is formed between each photoreceptor **120** and the vertical transfer register **122** provided on the right side of the photoreceptor **120**, which is not shown. Each of the photoreceptor **120** and the vertical transfer register **122** has the two layers which are formed in the region respectively and is set to have the same level, for example. Layers are provided by using silicon dioxide (SiO<sub>2</sub>) and resin to form two-layer polysilicon films **126a** and **126b** and a shielding film **128**. The two-layer polysilicon films **126a** and **126b** are connected to each other through a metal electrode, which is not shown. The shielding film **128** shields a light by using a material such as tungsten or aluminum. The shielding film **128** is formed to cover the periphery of the photoreceptor **120** and to completely cover the vertical transfer register **122** region.

In the embodiment, the two-layer polysilicon films **126a** and **126b** and the shielding film **128** form a mask by using a resist in such a manner that a light is incident in the vertical transfer register **122**. In a region in which the mask is formed, the resist of the mask corresponding to each of the films **126a**, **126b** and **128** is removed and SiO<sub>2</sub> (**130**) is provided as shown in a section so that the incidence hole **124** is formed. Furthermore, SiO<sub>2</sub> is provided and smoothed.

The color filter **12b** and an on-chip microlens are formed on the SiO<sub>2</sub>, which is not shown. When the color filter **12b** forms a color filter segment to cover only the photoreceptor **120** region, a white light is incident on the incidence hole **124**. In this case, a signal charge corresponding to a luminance signal is generated in the incidence hole **124**. In the case in which the incidence hole **124** is covered with a color filter segment having one of the primaries RGB, moreover, a signal charge having the color attribute of the same color filter segment is generated. The incidence hole **124** formed in the vicinity of a position treated as a virtual pixel is thus utilized as a new information source in image formation. The information sent from the incidence hole **124** is utilized in the static image photographing mode.

Next, the operation of the digital camera **10** will be described. FIG. **16** shows the main routine of the digital camera **10**. After a power source is turned ON, initialization is carried out. Then, a photographing mode is selected (a step **S1610**). For the mode selection, either a static image photographing mode or a dynamic image photographing (movie) mode is selected by the mode selecting section **24a**. A result of the selection is supplied as the mode signal **24c** to the system control section **26**. After the selection, the processing proceeds to through image display.

The through image display is an operation for displaying, on the monitor **32**, image data obtained by supplying the image data **20a** sent from the image pick-up section **12** to the signal processing section **22** and processing the same image data **20a** (a step **S1612**). In order to carry out this operation, the timing signal generating section **28** and the driver **30** are controlled by the system control section **26**. The AF regulation, the AE regulation and the mechanical shutter are brought into an opening state. The image pick-up section **12** photoelectrically converts an incident light in response to the

timing signal **28a** and ¼ thins a signal charge thus obtained in a vertical direction and then transfers the thinned signal charge, for example. The signal charge is changed into an analog signal through the FDA to be output to the preprocessing section **20**.

The signal processing section **22** fetches, into the memory, the image data **20a** converted by the preprocessing section **20**. In this case, the image data **20a** are thinned in a horizontal direction and are thus read as a dynamic image in the memory. The images thus thinned in the vertical and horizontal directions are supplied to the monitor **32**. The processing proceeds to the decision of the operation (to a step **S14**) while carrying out the through image display.

Next, it is decided whether the digital camera **10** is set in the static image photographing mode or not (the step **S14**). In the system control section **26**, the decision is carried out based on the result of the mode selection. If the static image photographing mode is selected (YES), the processing proceeds to static image photographing (a subroutine SUB1). Moreover, if the static image photographing mode is not selected (NO), the processing proceeds to a decision whether dynamic image photographing is selected or not (to a step **S16**).

This decision is carried out by the system control section **26** in the same manner as that in the case of the decision in the static image photographing. If the dynamic image photographing is selected (YES), the processing proceeds to the dynamic image photographing (a subroutine SUB2). Moreover, if the dynamic image photographing is not selected (NO), this state is maintained, that is, the processing proceeds to the through image display (to a step **S18**).

Also after the static image photographing (the subroutine SUB1) and the dynamic image photographing (the subroutine SUB2) are ended, the processing proceeds to the through image display (to the step **S18**). The digital camera **10** causes the monitor **32** to display the image of a field picked up by the image pick-up section **12** as described above.

When any of keys in the operating section **24** is manipulated, it is decided whether or not the key corresponds to the mode selecting section **24a** in the system control section **26** (a step **S20**). If the key corresponds to the mode selecting section **24a** (YES), it is decided that a mode change is set and the processing returns to the mode selection processing (to the step **S1610**). If the key does not correspond to the mode selecting section **24a** or the key operation is not carried out for a predetermined time (NO), moreover, the processing proceeds to a decision whether the operation of the digital camera **10** is ended or not (to a step **S22**).

Subsequently, the decision of the end is carried out (the step **S22**). If the decision is not ended (NO), the previous photographing mode is held as mode information and the processing returns to the decision of the static image photographing, and this processing is repeated (to the step **S14**). When any key operation in the digital camera **10** is not carried out over a standby time, the through image display may be stopped in the photographing mode to automatically move into a standby mode. If the decision is ended (YES), moreover, the power supply is turned ON to end the operation of the digital camera **10**. The result is supplied to the driver **30**.

Next, description will be given to the operation of the digital camera **10** in the static image photographing mode (the subroutine SUB1: see FIG. **17**). The release shutter button **24b** is operated in a half stroke (or up to a first stage) (**S1**: ON; a substep **SS10**). Then, the system control section **26** newly drives the image pick-up section **12** upon receipt

of the trigger signal **24d** corresponding to the operation (a substep SS12). The driving operation of the image pick-up section **12** is carried out in response to the driving signal **30d** supplied from the driver **30** corresponding to the control of the system control section **26** in the same manner as in case of the through image.

The AF/AE control is carried out based on the image data **20a** obtained by the driving operation of the image pick-up section **12** (a substep SS14). The signal processing section **22** generates a parameter for the AF regulation and the AE regulation in the evaluation value calculating section by using the supplied image data **20a**. The signal processing section **22** supplies a parameter **22d** to the system control section **26** through the data bus **22c** and the system bus **100**. The system control section **26** generates the control signal **26a** corresponding to the parameter **22d** and supplies the control signal **26c** to the timing signal generating section **28** and the driver **30** through the system bus **100**, respectively. The driver **30** generates the driving signals **30a** and **30b** for the AF/AE regulation in consideration of the control signal **26c** and the timing signal **28a** and supplies the same driving signals **30a** and **30b** to the optical lens system **14** and the diaphragm regulating mechanism **16**, respectively.

The AF/AE control may be carried out based on information obtained by using a sensor prepared separately for the AF/AE regulation. Moreover, it is apparent that the operation at **S1** is not restricted to a one-time operation but the above-mentioned processing is repeated when the operation of **S1** is carried out until regular image pick-up is started, which is not shown.

The release shutter button **24b** is operated in a full stroke (or up to two stages) (**S2**: ON; a substep SS16). Next, the system control section **26** controls to carry out the regular image pick-up for the image pick-up section **12** upon receipt of the trigger signal **24d** corresponding to this operation (a substep SS18). For the control, the mechanical shutter **18** is closed in response to the driving signal **30c** supplied from the driver **30** corresponding to the control of the system control section **26** and the signal charge stored in the vertical transfer register **122** is thus swept away. Then, the driver **30** supplies the driving signal **30d** to form a potential in the vertical transfer register **122**.

Thereafter, the mechanical shutter **18** is opened in response to the driving signal **30c** supplied from the driver **30** (the start of an exposure: a substep SS20). The system control section **26** also controls an exposure time based on the supplied parameter **22d**. At a substep SS22, whether the exposure time has passed is decided in the system control section **26**. If the passage of the exposure time is not completed (NO), the decision is repeated. Moreover, if it is decided that the exposure time has passed (YES), the processing proceeds to an exposure completion processing (to a substep SS24).

In the exposure completion processing, the driver **30** is controlled by the system control section **26** to supply the driving signal **30c** to the mechanical shutter **18** so that the mechanical shutter **18** is closed (a substep SS24). Consequently, the image pick-up section **12** is brought into a shielding state. First of all, the image pick-up section **12** reads a signal charge which is photoelectrically converted corresponding to an amount of a light incident through the incidence hole **124** in this state and is stored in the vertical transfer register **122** (the driving operation of a vertical transfer path: a substep SS26). The signal charge is horizontally transferred and is converted into an analog voltage signal to be supplied to the preprocessing section **20**. In the preprocessing section **20**, the analog voltage signal is con-

verted into a digital signal. The preprocessing section **20** outputs the image data **20a** to the memory of the signal processing section **22**. A processing in FIG. **18** is started through a connecting part A (to a substep SS28).

Next, the memory saves data transferred from the position of the virtual pixel which cannot be directly obtained (a substep SS28). After the data are saved, a signal charge is read from the photoreceptor **120** to the vertical transfer register **122** and all the pixels are thus read as usual (a substep SS30). The transfer of a signal charge, a Q/V conversion for the signal charge and a digital conversion for an analog signal are sequentially carried out so that the image data **20a** corresponding to the photoreceptor **120** are saved in the memory of the signal processing section **22** (a substep SS32).

Subsequently, a signal processing is carried out by using the image data **20a** thus saved (a substep SS34). In the signal processing section **22**, a gamma correction, a pixel interpolation processing, a matrix processing and a compression processing are sequentially carried out for the image data **20a**. In particular, the image data **20a** obtained from the incidence hole **124** in the image interpolation processing are used as luminance data  $Y_H$  in a virtual pixel position. The luminance data  $Y_H$  obtained actually can be used with higher level precision than the luminance data  $Y_H$  calculated by adding and averaging surrounding pixel data.

The image data obtained after the compression processing are supplied to and recorded in the storage **34** through the data bus **22c**, the system bus **100** and the data bus **34a** (a substep SS36). At almost the same time, in the signal processing section **22**, the image data thinned from the image data obtained before the compression may be supplied to and displayed on the monitor **32**.

Next, it is decided whether the digital camera **10** receives an instruction for continuous photographing or not (a substep SS38). More specifically, it is decided whether or not the release shutter button **24b** is continuously pushed into the stroke state in the **S2**. If the continuous photographing is to be carried out (YES), the processing returns to the AF/AE control shown in FIG. **17** through a connecting part B, for example (to the substep SS14) and each of the processings is repeated. If single photographing is to be carried out (NO), the processing proceeds to a decision whether the static image photographing mode is ended or not (to a substep SS40).

While the decision of the presence of the continuous photographing is carried out after the completion of the recording for convenience, a next exposure may be started if data are completely read from the image pick-up section **12**.

It is decided whether the operation in the static image photographing mode is ended or not (a substep SS40). If the static image photographing mode is continuously set (NO), the processing returns to the substep SS10 to be the first processing shown in FIG. **17** through a connecting part C and the past processings are repeated. Moreover, if the static image photographing mode is ended (YES), the processing moves to a return and the subroutine SUB1 is thus ended.

By such an operation, actual data are obtained in the vicinity of the virtual pixel. Therefore, a correlated decision processing is carried out by using the surrounding pixel data. If the correlation is present, estimation is carried out based on the addition and average of pixel data in a correlating direction. Consequently, it is possible to acquire information with higher level precision than that of the data of a virtual pixel to be calculated.



This relationship will be briefly described with reference to FIGS. 19(a) to 19(d). There is an object 44 shown in FIG. 19(a). The object 44 is divided into a black region 44a shown in cross hatching and a white region 44b through a stepped obliquely and rightward upward boundary 44c. 5 When the object 44 is photographed in a static image by means of the digital camera 10 according to the embodiment, the object 44, the photoreceptor 120 and the incidence hole 124 in the solid-state image pick-up device 12c have a relationship shown in FIG. 19(b). The photoreceptor (actual pixel) 120 is represented by a great circle shown in a solid line, the incidence hole 124 is represented by a small circle shown in a solid line, and the virtual pixel is represented by a small circle shown in a broken line.

By the static image photographing, for example, the incidence hole 124 in the black region 44a is set to have a level of 0 and the incidence hole 124 in the white region 44b is set to have a level of 1. At this time, an incidence hole 124A in the boundary 44c is set to have the level of 0. The incidence hole 124 which is provided obliquely and leftward downward is also set to have the level of 0. When a virtual pixel positioned in the vicinity of the boundary 44c has an estimation level of 0.3 by averaging using pixel data transferred from two obliquely adjacent photoreceptors (actual pixels) 120 through the boundary 44c and the actual data of the incidence hole 124A. When the level of the virtual pixel is calculated by utilizing this relationship, a virtual pixel provided leftward and obliquely downward also has the level of 0.3 and a value close to black is obtained. As a result, an image 46 shown in FIG. 19(c) is obtained. The image 46 reproduces the object 44 almost faithfully. 30

On the other hand, when a virtual pixel level corresponding to the incidence hole 124A is first calculated by using the past correlated decision processing, it is apparent that there is no correlation in horizontal and vertical directions. At this time, the level of the virtual pixel is calculated by averaging four surrounding actual pixels. The result of estimated calculation for the virtual pixel level is 0.5. In case of monochrome, a virtual pixel level of 0.5 corresponds to gray. As a result, an image 48 shown in FIG. 19(d) is obtained. In the image 48, a gray region 48a shown in hatching is formed in the vicinity of the boundary 44c corresponding to the position of the virtual pixel. The formation of the gray region 48a brings an image having filling so that the resolution of the image is deteriorated. 45

Even if an image has an oblique boundary such as a highlight white void, it is possible to represent an accurate contour without forming the gray region. Also in a color expression with a color image, it is possible to decrease the false signal of a color by utilizing the incidence hole 124. Thus, a color resolution can be enhanced. 50

Next, description will be given to the operation of the digital camera 10 in the dynamic image photographing mode (see FIG. 8). The dynamic image photographing has already been carried out in the state of through image display described above. For this reason, when the processing is moved to the dynamic image photographing mode in the subroutine SUB2, the AF/AE control is first carried out (a substep SS200). The release shutter button 24b is pressed corresponding to a full stroke in a timing desired by a user (the state of S2: a substep SS202). 55

The system control section 26 controls to carry out the regular image pick-up for a dynamic image for the image pick-up section 12 upon receipt of the trigger signal 24d corresponding to the operation (a substep SS204). For this control, the mechanical shutter 18 is maintained to be set in an opening state in response to the driving signal 30c 65

supplied from the driver 30 corresponding to the control of the system control section 26 and the signal charges stored in the vertical transfer register 122 are continuously swept away immediately before an exposure is started. Then, the driver 30 supplies the driving signal 30d to form a potential in the vertical transfer register 122.

Thereafter, an electronic shutter is turned OFF in response to the driving signal 30c supplied from the driver 30, thereby starting the exposure (a substep SS206). The system control section 26 also controls an exposure time from the supplied parameter 22d. It is decided whether the exposure time has passed or not in the system control section 26 (a substep SS208). If the passage of the exposure time is not completed (NO), the decision is repeated. Moreover, if it is decided that the exposure time has passed (YES), the processing proceeds to an exposure completion processing (to a substep SS210).

In the exposure completion processing, the driver 30 is controlled from the system control section 26 to supply the driving signal 30d to the image pick-up section 12, and the signal charge is field shifted to the vertical transfer register 122 (the substep SS210). The image pick-up section 12 sweeps the signal charge away also immediately before the exposure before the field shift is carried out. The processing of sweeping the signal charge from the vertical transfer register 122 is carried out again in this stage in order to make sure. The reason is that there is a possibility that an overflow might be caused when the signal charge is read from the adjacent photoreceptor 120 to the vertical transfer register 122 together with the signal charge which is photoelectrically converted and stored corresponding to the amount of a light incident through the incidence hole 124 in this state. 20

The signal charge read onto the vertical transfer register 122 is  $\frac{1}{4}$  thinned toward a horizontal transfer register (not shown) to carry out vertical mixing (a substep SS212). Furthermore, the signal charge is line shifted for a horizontal blanking period and is moved to the horizontal transfer register. The signal charge is horizontally transferred in the horizontal transfer register and is converted into an analog voltage signal to be supplied to the preprocessing section 20. In the preprocessing section 20, the analog voltage signal is converted into a digital signal. The preprocessing section 20 outputs the image data 20a to the memory of the signal processing section 22. Then, the image data 20a corresponding to the photoreceptor 120 are saved in the memory of the signal processing section 22. 45

Next, a signal processing is carried out by using the saved image data 20a (a substep SS214). First of all, the signal processing section 22 reads only any of the image data 20a which are stored in the memory and are supplied from the completely shielded vertical transfer register 122. More specifically, a horizontal thinning processing is carried out. Information sent from the other vertical transfer registers 122 having the incidence holes 124 formed therein are discarded. The vertical transfer register 122 having the incidence hole 124 formed therein suffers an incident light also during a transfer in addition to the read signal charge and is thus influenced by a smear. 50

In the case in which the solid-state image pick-up device 12c shown in FIG. 13 is used, the image data 20a are  $\frac{1}{3}$  thinned and read in a horizontal direction. In the signal processing section 22, a gamma correction, an image interpolation processing, a matrix processing and a compression processing are sequentially carried out for the image data 20a. The pixel interpolation processing is carried out in just the same procedure as before differently from the case of the 65

static image photographing mode. Moreover, the compression processing is carried out according to the standards of MPEG-1 and MPEG-2.

The image data obtained after the compression processing are supplied to and recorded in the storage **34** through the data bus **22c**, the system bus **100** and the data bus **34a** (a substep **SS216**). At almost the same time, in the signal processing section **22**, the image data thinned horizontally from the image data obtained before the compression may be supplied to and displayed on the monitor **32**.

Next, it is decided whether the dynamic image photographing mode is ended or not (a substep **SS218**). If the release shutter button **24b** is pressed corresponding to a full stroke again or a recording capacity is gone (YES), the system control section **26** outputs the control signal **26a** upon receipt of the trigger signal **24d** or according to the result of the detection of a capacity in the system control section **26**. At this time, dynamic image recording in the storage **34** is ended and the through image display is preferably carried out continuously. The processing moves to a return according to the decision of the end and the subroutine **532** is thus ended. Moreover, if the dynamic image recording is continuously carried out (NO), the processing returns to the decision whether the exposure is completed or not (the substep **SS208**) and the processings described above are repeated.

Thus, all of the vertical transfer registers **122** are not provided with the incidence hole **124** but there is provided the vertical transfer register **122** which is shielded in such a manner that the color of the image data **20a** obtained when horizontally thinning the color array pattern of the color filter **12b** has the color array pattern of the color filter **12b** in the signal processing section **22**. Consequently, the dynamic image photographing can also be implemented.

While the incidence hole **124** in the solid-state image pick-up device **12c** is provided in the left one of the vertical transfer registers **122** making a set of two lines in the example described above, the incidence hole **124** may be provided in the right vertical transfer register **122** (see FIG. **21**). Since the vertical transfer register **122** which is completely shielded every three lines is provided,  $\frac{1}{3}$  thinning can be carried out in the horizontal direction by the signal processing section **22**.

Moreover, when the color filter **12b** uses the G square RB perfect checker pattern, it is possible to carry out  $\frac{1}{5}$  thinning or  $\frac{1}{7}$  thinning in the horizontal direction in consideration of the position of the vertical transfer register **122** to be utilized in a dynamic image as shown in FIGS. **22** and **23**. In the static image photographing, more incidence holes **124** are better. It is preferable that the thinning in the horizontal direction should be set in consideration of a balance with the number of pixels to be utilized in a dynamic image. In the G square RB perfect checker pattern, the horizontal thinning is carried out with  $1/x$  ( $x$  is an odd number) depending on the pattern.

Moreover, the horizontal thinning is not restricted to the even horizontal thinning as described above but the incidence hole **124** of the solid-state image pick-up device **12c** may be formed to carry out uneven horizontal thinning.

By the structure described above, the digital camera **10** carries out an exposure by utilizing the mechanical shutter **18**, first reads data sent from the incidence hole as the actual data of a virtual pixel in the static image photographing mode, then reads a signal charge from the photoreceptor **120** onto the vertical transfer register **122** in a shielding state, and for example, sets the actual data as luminance data  $Y_H$  and carries out an interpolation by using an actual pixel and the

actual data in the signal processing section **22**, thereby generating an image. Consequently, the precision of image data can be more enhanced than that of image data based on the estimation of the virtual pixel. Thus, image display can be carried out accurately. In particular, a contour in an oblique direction can be reproduced faithfully and the false signal of a color can be decreased to enhance a color resolution.

In the digital camera **10**, moreover, the signal processing section **22** thins and reads, in a dynamic image photographing mode, only a signal read from the vertical transfer register **122** which has no incidence hole and is shielded. Consequently, it is possible to obtain a dynamic image without the influence of a smear. Thus, both the static image photographing mode and the dynamic image photographing mode can be implemented by one solid-state image pick-up device.

Furthermore, the solid-state image pick-up device **12c** is provided with the adjacent photoreceptor **120** to the photoreceptor **120** shifted by an almost half pitch pixel and a set of vertical transfer registers **122** and **122** in two lines are consequently formed to meander between the photoreceptors **120** in a row direction, the vertical transfer register **122** which is shielded and the vertical transfer register **122** having the incidence hole **124** formed therein are regularly provided, and the vertical transfer register **122** which is shielded is provided in such a manner that the image data obtained by the horizontal thinning maintain the same relationship with the color array pattern of the color filter segments R, G and B covering the photoreceptor **120** which is adjacent to the vertical transfer register **122** by aiming at the same color array pattern. Consequently, it is possible to implement both the static image photographing mode and the dynamic image photographing mode by one solid-state image pick-up device.

According to the invention, imaginary pixel point data corresponding to the amount of a received light on an imaginary pixel point can be obtained separately from image data. Therefore, it is possible to correct the image data by using the imaginary pixel point data, thereby creating an image with a high resolution and high precision.

Further, a static image having a high finesses and picture quality can be picked up, a smear can be reduced also when a dynamic image is picked up.

Still further, the shielding means is utilized to carry out an exposure, data sent from an opening are first read as the actual data of a virtual pixel in static image photographing, a signal charge is then read from the photoreceptor onto the vertical transfer means in a shielding state and the same actual data are set to be luminance data, for example, and an interpolation is carried out by using an actual pixel and the actual data through the signal processing means to generate an image. Consequently, the precision of the image data can be more enhanced than that of image data based on the estimation of the virtual pixel. As a result, image display can be carried out accurately. In the dynamic image photographing, thus, the signal processing means horizontally thins and reads only the signal read from the shielded vertical transfer means having no opening. Consequently, it is possible to obtain a dynamic image without the influence of a smear.

According to the solid-state image pick-up device in accordance with the invention, moreover, signal reading in the dynamic image photographing is carried out and actual data obtained from a signal charge supplied from an opening positioned in the vicinity of a virtual pixel in addition to the signal charge supplied from the photoreceptor provide information having higher precision than that of the estimation

data of the virtual pixel which are generated by the interpolation, while vertical thinning is carried out to read and transfer the signal charge, thereby performing the signal reading in the dynamic image photographing. In the signal reading in the dynamic image photographing, it is possible to obtain normal data maintaining a color array pattern for the dynamic image photographing by using only the data corresponding to any of the read signal charges which is obtained from the first vertical transfer means. In the solid-state image pick-up device, it is possible to implement both the static image photographing mode and the dynamic image photographing mode by one solid-state image pick-up device.

The invention claimed is:

1. A solid-state image pick-up device comprising:
  - photoelectric converting devices formed at first array intervals in row and column directions on a semiconductor substrate;
  - vertical transfer paths provided in the column direction and serving to read and transfer signal charges obtained by the photoelectric converting devices; and
  - a shielding film that covers an upper part of the vertical transfer paths, wherein:
    - a plurality of shieldless apertures are formed in each of a plurality of said vertical transfer paths and in positions corresponding to imaginary pixel point positions in the shielding film; and
    - the shieldless apertures are arranged at second array intervals in the row and column directions.
2. The solid-state image pick-up device according to claim 1, wherein the photoelectric converting devices are arranged in the row direction with a shift of a  $\frac{1}{2}$  pitch alternately.
3. A digital still camera comprising:
  - the solid-state image pick-up device according to claim 1 or 2;
  - a mechanical shutter provided in a front part of the solid-state image pick-up device; and
  - an image processing device for reading imaginary pixel point charges stored in the imaginary pixel point positions on the vertical transfer paths from the solid-state image pick-up device after the mechanical shutter is closed and then reading a signal charges of the photoelectric converting devices from the solid-state image pick-up device, thereby generating image pick-up data from the signal charges and the imaginary pixel point charges.
4. The solid-state image pick-up device according to claim 1, wherein each photoelectric converting device is disposed between a pair of the shieldless apertures that are adjacent to each other in the column direction and between a pair of the shieldless apertures that are adjacent to each other in the row direction.
5. The solid-state image pick-up device according to claim 1, wherein each shieldless aperture is formed above a channel stop between the adjacent vertical transfer paths.
6. A solid-state image pick-up device comprising:
  - photoelectric converting devices formed at first array intervals in row and column directions on a semiconductor substrate;
  - vertical transfer paths provided in the column direction and serving to read and transfer signal charges obtained by the photoelectric converting devices;
  - a shielding film that covers an upper part of the vertical transfer paths; wherein a plurality of shieldless apertures are formed in each of a plurality of said vertical transfer paths and in positions corresponding to imagi-

- nary pixel point positions in the shielding film, and the shieldless apertures are arranged at secondary array intervals in the row and column directions; and
- a storage section that stores electric charges transferred along the vertical transfer paths by a predetermined number of lines, the storage section that transfers the electric charges to a horizontal transfer path, the storage section provided in a connecting portion between the vertical transfer paths and the horizontal transfer path.
7. The solid-state image pick-up device according to claim 6, wherein the photoelectric converting devices are arranged in the row direction with a shift of a  $\frac{1}{2}$  pitch alternately.
8. A digital still camera comprising:
  - the solid-state image pick-up device according to claim 6 or 7;
  - a mechanical shutter provided in a front part of the solid-state image pick-up device; and
  - a controller that drives the vertical transfer paths at a higher speed than a transfer speed of a static image to fetch, to the storage section, only signal charges of a valid line constituting a dynamic image when photographing the dynamic image with the mechanical shutter opened.
9. The solid-state image pick-up device according to claim 6, wherein each photoelectric converting device is disposed between a pair of the shieldless apertures that are adjacent to each other in the column direction and between a pair of the shieldless apertures that are adjacent to each other in the row direction.
10. The solid-state image pick-up device according to claim 6, wherein each shieldless aperture is formed above a channel stop between the adjacent vertical transfer paths.
11. A solid-state image pick-up device comprising:
  - photoreceptors provided in a two-dimensional array and serving to convert incident light into signal charges;
  - a plurality of vertical transfer paths that transfers the signal charges converted by the photoreceptors in a vertical direction; and
  - a horizontal transfer path that transfers the signal charges transferred in a horizontal direction which is orthogonal to the vertical direction, wherein:
    - an interval between the photoreceptors provided in the vertical and horizontal directions is set to be a pitch,
    - the photoreceptors which are adjacent to each other are provided with a shift of an almost half pitch,
    - the vertical transfer paths are formed to make pairs of two lines between the photoreceptors provided in the horizontal direction,
    - the vertical transfer paths are caused to make a detour every line for the photoreceptors which are adjacent to each other,
    - the photoreceptors that are actually provided are set to be actual pixels,
    - photoreceptors assumed to be provided in a space region surrounded by the actual pixels are set to be virtual pixels,
    - the vertical transfer paths include first vertical transfer paths which are shielded and second vertical transfer paths, each having a plurality of optical openings formed in the vicinity of the virtual pixels, and
    - the first and second transfer paths are provided regularly;
  - a shielding member that regulates an exposure time of the solid-state image pick-up device; and

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a signal processor that carries out an interpolation processing based on signals obtained from the actual pixels using signals obtained from the openings as actual data of the virtual pixels.

12. The solid-state image pick-up device according to claim 11, wherein each of the opening has a size set within a packet for storing the signal charge.

13. The solid-state image pick-up device according to claim 11 or 8, wherein:

the signal processor carries out a thinning processing in the horizontal direction by using the signals obtained from the actual pixels through the first vertical transfer path in each pairs of the vertical transfer paths in two lines which serve to transfer the signal charges of the photoreceptors in a dynamic image photographing mode for reading at a predetermined interval in contrast with a static image photographing mode in which all of the actual data of the actual pixel and the virtual pixel are used, and

the first transfer paths are shielded with an array of color filter segments for separating colors.

14. The solid-state image pick-up device according to claim 11 or 8, wherein the solid-state image pick-up device carries out thinning reading in the vertical direction in the dynamic image photographing mode.

15. The solid-state image pick-up device according to claim 11 or 8, wherein the signals obtained in the openings are used as information of the virtual pixels in a static image photographing mode.

16. A solid-state image pick-up device comprising:  
photoreceptors provided in a two-dimensional array and serving to convert incident light into signal charges;  
a plurality of vertical transfer path that transfers the signal charges converted by the photoreceptors in a vertical direction;

a horizontal transfer path that transfers the transferred signal charges in a horizontal direction which is orthogonal to the vertical direction, wherein:

an interval between the photoreceptors provided in the vertical and horizontal directions are set to be a pitch,

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the photoreceptors which are adjacent to each other are provided with a shift of an almost half pitch,

the vertical transfer paths are formed to make pairs of two lines between the photoreceptors provided in the horizontal direction and are caused to make a detour every line for the photoreceptors which are adjacent to each other,

the photoreceptors that are actually provided are set to be actual pixels,

photoreceptors assumed to be provided in a space region surrounded by the actual pixels are set to be virtual pixels,

the vertical transfer paths include first vertical transfer paths which are shielded and second vertical transfer paths having optical openings formed in the vicinity of the virtual pixels,

the first and second transfer paths are provided regularly, and

the first vertical transfer paths are provided in such a manner that a positional relation among colors of filters corresponding to photoreceptors adjacent to the first vertical transfer paths is identical with a positional relation among colors of filters corresponding to photoreceptors adjacent to the vertical transfer paths.

17. The solid-state image pick-up device according to claim 16, wherein each of the opening has a size set within a packet for storing the signal charge.

18. The solid-stage image pick-up device according to claim 16 or 13, wherein signals obtained from the openings are used as information of the virtual pixels in a static image photographing mode in which all of actual signals obtained from the actual pixels and the virtual pixels are used.

19. The solid-stage image pick-up device according to claim 16 or 13, wherein thinning reading in the vertical direction is carried out in a dynamic image photographing mode for reading at a predetermined interval in contrast with the static image photographing mode.

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